B20
L237

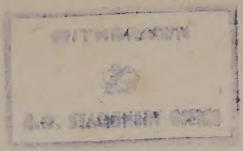
REFERENCE LIBRARY

COLLEGE OF ARCHITECTURE

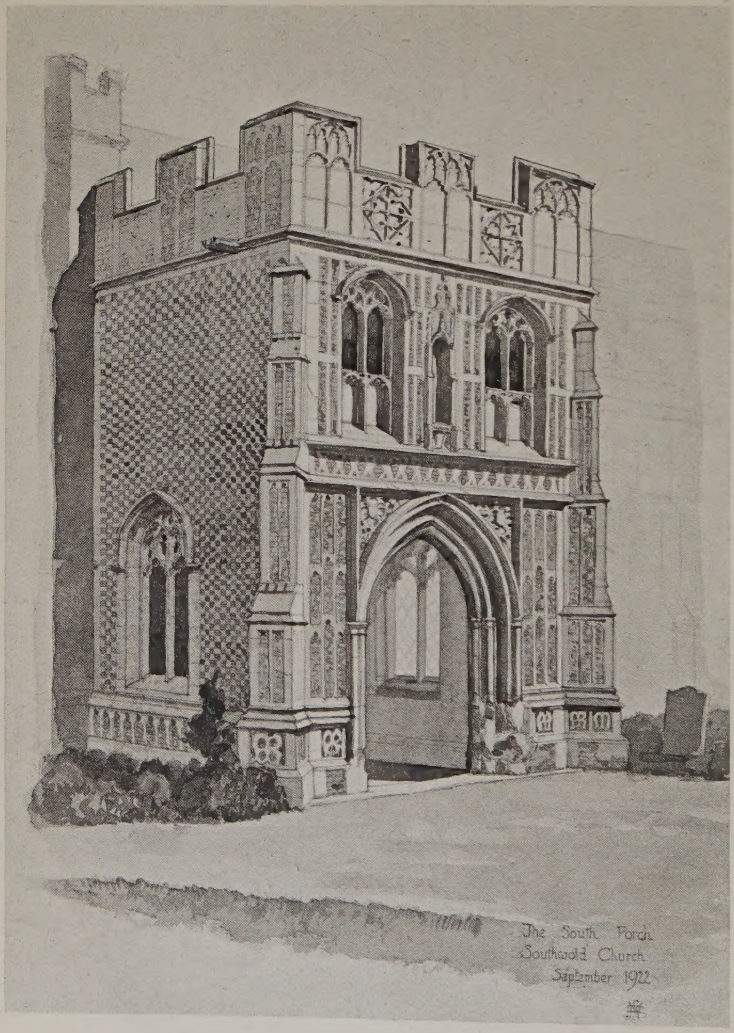
UNIVERSITY OF ARIZONA

PRESENTED TO
THE LIBRARY
BY Federal Government
Title 6

CAT.
19/5
464/M/604



A Short History
of the
Building Crafts



THE SOUTH PORCH, SOUTHWOLD CHURCH

Showing decorative use of flint and limestone

A Short History of the Building Crafts

by

Martin S. Briggs, F.R.I.B.A.

Author of *Baroque Architecture*
Muhammadan Architecture in Egypt and Palestine, &c.

ILLUSTRATED BY THE AUTHOR

OXFORD
At the Clarendon Press
1925

REFERENCE LIBRARY
COLLEGE OF ARCHITECTURE
UNIVERSITY OF ARIZONA

Oxford University Press
London Edinburgh Glasgow Copenhagen
New York Toronto Melbourne Cape Town
Bombay Calcutta Madras Shanghai
Humphrey Milford Publisher to the University

Printed in England

REFERENCE LIBRARY
COLLEGE OF ARCHITECTURE
UNIVERSITY OF ARIZONA

PREFACE

This book had its origin in a series of lectures to architectural students at University College, London, in the spring of 1922, and in subsequent articles published in *The Builder* during the same year. By the courtesy of the Editor, I am enabled to use a part of the letterpress and many of the illustrations which appeared in that journal, but the whole of the letterpress has since been recast and greatly amplified, and a number of new illustrations have been added. Of the 259 illustrations included in the present volume 253 are drawn by myself, and 6 (Figs. 8, 151A (4), 151B, 170A, 176A, 176B, and 205A) are reproduced direct from the books named in the 'List of Illustrations'. Over fifty of my own drawings were made on the spot or, in a few cases, from photographs. The remainder are adapted from other publications, old and new. Mr. Batsford has given his consent to the redrawing of 85 illustrations from books produced by his firm, of which approximately half are selected from his admirable series of *Old English Cottages* (in Kent and Sussex, Surrey, the Cotswolds, and East Anglia), 18 from Garner and Stratton's *Tudor Architecture*, 11 from Weaver's *English Leadwork*, 6 from Day's *Windows*, and the remainder from other works cited in the 'List of Illustrations'. Figs. 122 and 123

are drawn from material kindly supplied to me by Mr. James Burford. Figs. 184–6 and 199–200 are based on drawings in Mr. Sydney Jones's *Village Homes of England*, and Figs. 148, 151A (3), and 183 on drawings and photographs in Mr. Innocent's *Historical Development of English Building Construction*, both of which books will be found useful companions to this volume. From Mr. J. de M. Johnson of the Clarendon Press I have received much help and valuable advice throughout the preparation of the work. In making some of the drawings in the later chapters I was assisted by Mr. H. R. L. Knight.

The twofold object of this book is to serve on the one hand as a companion to existing text-books of architectural history and of building construction, thus enabling a student of architecture to realize more clearly the close but often forgotten relation between the two; on the other hand to remind the various branches of building craftsmen of the position of their ancestors in architectural history, and to tell something of bygone methods of work.

At a later date I hope to publish a study of *The Architect in History*, a topic to which allusion is made in the first chapter of this book.

M. S. B.

Mill Hill.
New Year, 1925.

CONTENTS

	PAGE
Preface	v
I. The Architect, the Craftsman, and the Past	1
II. Brickwork	37
III. Masonry	72
IV. Concrete	105
V. Carpentry	116
VI. Joinery	143
VII. Ironwork	168
VIII. Roof Coverings	202
IX. Plasterwork	223
X. External Plumbing	240
XI. Glazing	260
Index	284

LIST OF ILLUSTRATIONS

Frontispiece

The South Porch, Southwold Church, showing decorative use of flint and limestone (original drawing by author).

The Golden Cross Inn, Coventry . . . . *facing page* 1
(original drawing by author)

FIG.		PAGE
1	Egyptian concave foundations (Flinders Petrie) . .	39
2	Typical Egyptian bonding (Prisse d'Avennes) . .	39
3	Egyptian elliptical arch (F. M. Simpson) . . .	39
4	Mesopotamian vault in brick (Place et Thomas) . .	39
5	Roman bonding according to Vitruvius . . .	47
6	Byzantine brick oversailing courses, Ravenna (Author, from a photograph)	47
7	Byzantine brick arch and dentil courses, Salonika (Author)	49
8	Ornamental brickwork at Lazaritza, Serbia (Author) .	49
9	Brick arch imitated in masonry, Cairo (Author) . .	49
10	Typical 'Delta' brickwork, Rosetta (Author) . .	49
11	Brick cornice, Rome (Author)	49
12	Brick arcading and cornice, Rome (T. G. Jackson) .	49
13	Ornamental brickwork, Toscanella (T. G. Jackson) .	49
14	Typical Veronese brick battlement (Street) . .	55
15	Venetian brick chimney (Street)	55
16	Typical Veronese brick arch (Street)	55
17	Typical Veronese brick arch (Street)	55
18	Cusped brick window from Coccaglia (Street) . .	55
19	Brick cornice from Broletto, near Brescia (Street) .	55
20	Brick arch and mullion, Layer Marney (Garner and Stratton)	59
21	Diaper pattern in brick, Pooley Hall, Warwick (Garner and Stratton)	59
22	Brick oversailing courses to chimney-stack (Oliver, *East Anglia*)	59

FIG.		PAGE
23–5	Plans of East Anglian chimney-stacks (Oliver, *East Anglia*)	59
26	Typical East Anglian chimney-stack (Oliver, *East Anglia*)	59
27	Kentish brick gable (Dawber, *Kent and Sussex*)	61
28	Kentish brick gable (Dawber, *Kent and Sussex*)	61
29	East Anglian brick gable (Oliver)	61
30	Brick gable from Woking (Curtis Green, *Surrey*)	61
31	Plain brick chimney caps from Kent and Sussex (Dawber)	63
32	Plain brick chimney caps from Surrey (Curtis Green)	63
33	Arcaded chimney-stack (Dawber)	63
34	Arcaded chimney-stack, Marlborough College (Author, from a photograph)	63
35–40	Plans of chimney-stacks from Surrey (Curtis Green)	63
41	Cradles used in Egypt for moving stone blocks (Flinders Petrie)	75
42	Stone facing of the Great Pyramid (F. M. Simpson)	75
43	Construction of Egyptian stone walls (Choisy, *L'art de bâtir chez les Égyptiens*)	75
44	Construction of Egyptian pylons (Choisy, *L'art de bâtir chez les Égyptiens*)	75
45	Assyrian bonding (Place et Thomas)	75
46	Typical Greek masonry (Penrose)	78
47	Greek lintel in three stones (Durm)	78
48	Drum of Parthenon columns, showing sinking (Author)	78
49	'Plugs' from Temple at Bassae (Cockerell)	78
50–3	Greek dowels and cramps (Various sources)	78
54	Frieze of Parthenon showing use of metal cramps (Penrose)	79
55	Use of cramps in Temple at Bassae (Cockerell)	79
56	Method of raising stones of entablature at Aegina (Cockerell)	81
57	Method of rolling large stones by means of a cradle (Hittorff and Zanth)	81
58	Use of *ancones* for raising large drums of Parthenon columns (Author)	81
59	Roman stone lintel at Arles (Choisy, *L'art de bâtir chez les Romains*)	83

FIG.		PAGE
60	Arch-construction at the Pont du Gard (Choisy, *L'art de bâtir chez les Romains*)	83
61	Roman roof at Chaqqa, of stone slabs on arches (De Vogüé, *Syrie Centrale*)	83
62	Construction of a Roman stone entablature (Rondelet, *L'art de bâtir*)	83
63–4	Byzantine use of metal collars and lead seatings (Choisy, *L'art de bâtir chez les Byzantins*)	85
65	Saracenic joggled step from Cairo (Author)	87
66	Saracenic joggled voussoir from Cairo (Author)	87
67	Saracenic joggled lintel from Cairo (Author)	87
68	Pier from S. Ambrogio at Milan (Cummings)	89
69	Lintel and tympanum, Notre-Dame du Port, Clermont-Ferrand (Author, from a photograph)	89
70	Construction of stone pendants, Henry VII's Chapel, Westminster (Willis)	93
71	Construction of a keystone to a Gothic vault (Viollet-le-Duc)	93
72	Section of part of arcade, Whitby Abbey (F. Bond)	93
73	Method of fixing marble shafts to Gothic piers (Viollet-le-Duc)	93
74	Stone annulet for marble shaft, built into wall (Viollet-le-Duc)	93
75	Metal ring to secure marble shaft (Viollet-le-Duc)	93
76	Typical Yorkshire chimney-stack (G. Sanderson)	97
77	Yorkshire stone gable-end (G. Sanderson)	97
78	Yorkshire stone finial and kneeler (G. Sanderson)	97
79	Yorkshire stone coping (L. Ambler)	97
80–1	Yorkshire stone door-heads (G. Sanderson)	97
82–5	Cotswold stone door-heads (Dawber, *Cotswolds*)	99
86–7	Cotswold stone copings (Dawber, *Cotswolds*)	99
87A and B	Roman marble facing (Middleton, *Antiquities of Rome*)	103
87C	Section of cornice, Strozzi Palace, Florence (Stegmann and Geymüller)	103

FIG.		PAGE
88	Roman concrete walling, with facing of *opus reticulatum* on right and triangular bricks on left (after Middleton, *Antiquities of Rome*)	107
89	Method of building Roman concrete wall (Choisy, *L'art de bâtir chez les Romains*)	107
90	Roman hollow vaulting-arches (Choisy, *L'art de bâtir chez les Romains*)	107
91–2	Sections of Roman brick vaulting-ribs (Choisy, *L'art de bâtir chez les Romains*)	107
93	Roman flat vaulting-arches (Choisy, *L'art de bâtir chez les Romains*)	107
93A	The Roman Wall of London (Author, after F. W. Reader's restoration)	109
94–5	Byzantine brick lacing-courses in concrete (Choisy, *L'art de bâtir chez les Byzantins*)	111
96	Byzantine stone-facing to rubble walls (Choisy, *L'art de bâtir chez les Byzantins*)	111
97	Byzantine brick and stone in alternate courses (Choisy, *L'art de bâtir chez les Byzantins*)	111
98	Egyptian method of sawing timber (Choisy, *L'art de bâtir chez les Égyptiens*)	117
99–100	Ancient Egyptian timber wall-plates (Choisy, *L'art de bâtir chez les Égyptiens*)	117
101	Restoration of roof of the Arsenal at the Piraeus (Choisy, *Études épigraphiques*)	117
102	Restoration of a span-roof at Pozzuoli (Choisy, *L'art de bâtir chez les Romains*)	121
103	Roof-trusses at Old St. Peter's, Rome (Choisy, *L'art de bâtir chez les Romains*)	121
104	Roof of the courtyard of a Roman house (Choisy, *L'art de bâtir chez les Romains*)	121
105	Use of tie-beams in an Egyptian house (Author)	121
106	Roof over vault, earliest form, at S. Ambrogio, Milan (Dartein)	125
107	Roof over vault, with tie-beam, Montpezat (Dartein)	125
108	Roof over vault, with diagonal braces, Autun (Viollet-le-Duc)	125
109	Roof truss at Peterborough Cathedral (Rupprich-Robert)	125

FIG.		PAGE
110	Roof over aisle, New Walsingham (Brandon)	125
111	Roof over an aisle. French type (J. F. Choisy)	125
112	Roof of North Walsham Church (Brandon)	127
113	Roof of S. Porch, Heckington Church (Brandon)	127
114	Roof over nave, Lympenhoe Church (Brandon)	127
115	Roof over nave and aisles, Long Stanton Church (Brandon)	127
116	Curved brace roof (Jackson, *Gothic Architecture*)	129
117	Hammer beam roof (Jackson, *Gothic Architecture*)	129
118	Typical cottage roof, Surrey (Curtis Green, *Surrey*)	131
119	Roof of barn at Wipley Farm, Surrey (Curtis Green, *Surrey*)	131
120	Roof of the Guest House, Lingfield, Surrey (Curtis Green, *Surrey*)	131
121	Roof of a house at Godstone, Surrey (Curtis Green, *Surrey*)	131
122	Roof of barn at Stone, Bucks. (J. Burford)	131
123	Roof of barn at Harmondsworth, Middlesex (J. Burford)	131
124	Diagram of half-timber construction (Curtis Green)	133
125	Half-timber with brick filling, West Stow Hall (Garner and Stratton)	133
126	Half-timber with stone filling, Great Chalfield (Garner and Stratton)	133
127	Half-timber with plaster filling, Gainsborough Hall (Garner and Stratton)	133
127A	Eaves brackets at Pazzi Chapel, Florence (Geymüller)	135
127B	Coffered ceiling at S. Maria Maggiore, Rome (Letarouilly)	135
128	Egyptian door at British Museum (Author)	145
129	Egyptian chair at British Museum (Author)	145
130–1	Joints of last in detail (Author)	147
132–3	Details of Saracenic lattices (*mashrabiyyah*) (Prisse d'Avennes)	151
134–5	Saracenic doors in V. and A. Museum (Author)	151
136	Door from Clare, V. and A. Museum (Author)	154
137	Door from Ipswich, V. and A. Museum (Author)	154
138	Door from Michelney (Garner and Stratton)	154
139	Door, Abbot's Hospital, Guildford (Curtis Green)	154

FIG.		PAGE
140	Door from Bexon, Kent (Garner and Stratton)	154
141	Early Tudor panelling, Lydiate Hall (Garner and Stratton)	155
142	Early Tudor panelling, house at Taunton (Garner and Stratton)	155
143	Panelling from Monmouth, V. and A. Museum (Author)	156
144	Sixteenth century panelling, V. and A. Museum (Author)	156
145	Panelling from Waltham Abbey, V. and A. Museum (Author)	156
146	Open ceiling, Crowhurst Place (Curtis Green)	157
147	Typical Yorkshire open ceiling (Ambler)	157
148	Typical Yorkshire open ceiling (Innocent, *English Building Construction*)	157
149	Typical Jacobean panelling (Garner and Stratton)	157
150–1	Panelled doors from Hampton Court, V. and A. Museum (Author)	157
151A	(1) Wooden latch, Saracenic, from Cairo (Lane, *Modern Egyptians*)	163
	(2) Wooden latch, Saracenic, from Damascus (Author)	163
	(3) Wooden latch, English, from Yorkshire (Innocent)	163
	(4) Restored Roman Lock (British Museum, *Antiquities of Roman Britain*)	163
151B	Joiners' Tools (Moxon's *Mechanick Exercises*, 1678)	165
152	Roman window spikes (Author)	175
153	Door clamp, Gallo-Roman (Starkie Gardner, *Ironwork*)	175
154	Door hasp, Gallo-Roman (Starkie Gardner, *Ironwork*)	175
155	Roman strap-hinge (Author)	175
156	Norman ironwork, Stillingfleet (Author, from a photograph)	179
157	Hinges from North Door, Durham (Author, from a photograph)	179
158	Hinges from Worksop Priory (Starkie Gardner)	179
159	Grille from Lincoln, V. and A. Museum (Author)	179
160	S. Swithin grille, V. and A. Museum (Author)	179
161	Grille of treasury, Canterbury (Starkie Gardner)	181
162	Grille from St. Alban's, V. and A. Museum (Author)	181

FIG.		PAGE
163	Grille from Chichester, V. and A. Museum (Author)	181
164	Grille from Westminster, V. and A. Museum (Author)	181
165	Grille from Canterbury, V. and A. Museum (Author)	181
166	Handle with pierced tracery, Stogumber Church (Starkie Gardner)	185
167	Cockspur hinge (Garner and Stratton)	185
168–9	Tudor door-handles (Garner and Stratton)	185
170	Gates and railings formerly at Carshalton Park (Author)	193
170A	Smiths' tools (Moxon's *Mechanick Exercises*, 1678)	197
171	Diagram showing Egyptian flat roof (Choisy, *Égyptiens*)	203
172	Diagram showing Egyptian rock-tomb (Choisy, *Égyptiens*)	203
173	Modern flat roof as used in Egypt (Author)	203
174	Terra-cotta wall at Olympia (Bell, *Hellenic Architecture*)	205
175	Marble tiling at the Parthenon (Penrose)	205
176	Marble tiling at the Temple of Rhamnus (*Antiquités inédites de l'Attique*)	205
176A	Roman roofing tiles, London (British Museum, *Antiquities of Roman Britain*)	207
176B	Roman stone slates, Fifehead Neville, Dorset (British Museum, *Antiquities of Roman Britain*)	207
177	Typical Romanesque tiling (J. F. Choisy)	209
178	Typical Gothic parapet-gutter (Viollet-le-Duc)	211
179	Diagram showing evolution of gargoyle (Leblan)	211
180	Diagram showing evolution of gargoyle (Viollet-le-Duc)	211
181	Method of draining gutter through flying-buttress (Bond)	211
182	Typical Gothic parapet gutter (Viollet-le-Duc)	211
183	Thatching methods, Isle of Man (Innocent)	213
184–6	Methods of finishing thatched eaves (Jones, *Village Homes*)	213
187	Cotswold stone roof-ridge (Dawber, *Cotswolds*)	215
188	Method of sawing stone roof-ridges (Dawber, *Cotswolds*)	215
188A	Timber-framed house hung with slates, Blois (Author)	218
188B	Timber-framed house hung with slates, Blois (Author)	219
189–92	Ornamental tiling from Surrey cottages (Curtis Green)	221
192A	Egyptian plasterer's hand-float, British Museum (Author)	225

FIG.		PAGE
193–4	Stucco details from church of Germigny-des-Prés (Viollet-le-Duc)	230
195	Saracenic pierced panel (Millar, *Plastering*)	231
196	Saracenic pierced stucco panel (Author)	231
197	Diagram of wattle and daub construction (Bankart)	233
198	Plastered house, Thetford (Author, from a photograph)	234
199–200	Ornamental parging patterns (Jones, *Village Homes*)	235
201–5	Ornamental parging patterns (Oliver, *East Anglia*)	235
205A	Roman water pipes (I–III after Middleton, IV original sketch by author)	243
205B	A plumber's shop, seventeenth century (Félibien, *Principes de l'Architecture*, 1676)	249
206–8	French roof-plumbing, Chartres Cathedral (Viollet-le-Duc)	250
207–9	French Gothic eaves gutters &c. (Viollet-le-Duc)	251
210–12	Method of securing lead on spires &c. (Viollet-le-Duc)	252
213	Lead spire at Godalming (Author, from a photograph)	253
214	Lead spire at Chesterfield (Author, from a photograph)	253
215	Lead pipe-head from Knole (Weaver, *English Leadwork*)	257
216	Ornamental gutter from Winchester (Weaver, *English Leadwork*)	257
217	Ornamental lead ears (Weaver, *English Leadwork*)	257
218	Ornamental gutter from Bramhall (Lethaby, *Leadwork*)	257
219	Ornamental pipe from Bramhall (Weaver, *English Leadwork*)	257
220	Lead pipe-head from Petworth (Weaver, *English Leadwork*)	257
221	Saracenic 'pierced lattice' (L. F. Day, *Windows*)	267
222–3	Examples of 'roundel' glazing (L. F. Day, *Windows*)	267
224	Early medieval glazing from Aix-la-Chapelle (Day, *Windows*)	269
225–6	'Medallion' designs in window-glazing (Day, *Windows*)	271
227–30	Examples of Elizabethan glazing (Garner and Stratton)	277
231	Ornamental casement fastener (Garner and Stratton)	279
232	Method of using lead ventilating quarries (Author, from a photograph)	279
233–8	Lead ventilating quarries (Weaver, *English Leadwork*)	281

The Golden Cross Inn, Coventry
A fine example of timber framing (see p. 132)
(From a sketch by the Author)

I

THE ARCHITECT, THE CRAFTSMAN, AND THE PAST

Though most thoughtful people would agree that there is some subtle distinction between architecture and mere building, it has taxed the ability of many practised writers to define this difference in words. It has been assumed too readily that any building which is sufficiently old is, for that reason alone, a work of architecture. Hence, though there are histories of architecture innumerable, no author has yet been bold enough to essay a history of building in English. M. Choisy has written an admirable series of learned volumes in French,[1] constituting a mine of information that has been freely drawn upon for the present slender work. He examined the buildings of the past from a technical rather than an artistic point of view, and the fact that English writers have apparently neglected this field hitherto probably indicates that they imagined the name of building to be less popular with the public than that of architecture. This assumption is abundantly confirmed by an examination of present-day opinion. The man in the street is only too ready to offer his views, in the press and elsewhere, on any matter connected with architecture (which he regards as an art, to be criticized and controlled by individual taste), whereas he rightly recognizes building as an abstruse technical

[1] See acknowledgement in my 'Prefatory Note'.

subject demanding at least some knowledge. Further, he appears to be convinced that all architecture of the past is admirable, and that all modern buildings are bad; also, and paradoxically, that all modern architects are hide-bound pedants, far too prone to slavish copyism of ancient monuments. The general public will flock to lectures on architecture offered by any person who cares to discourse on that topic; but to advertise a series of popular lectures on building would be to court certain disaster.

A lack of enthusiasm for purely constructional problems is excusable to a certain extent on the part of young students, because building only becomes really interesting when one has to deal with it in actuality. But practising architects themselves are not altogether free from this thraldom, for too many of them display a frantic enthusiasm for preserving anything and everything that is merely old, while the newspapers cheerfully continue to abuse them for their alleged ignorance of acoustics and their hostility or indifference to 'new' materials such as plate-glass and reinforced concrete.

A knowledge of the history of architecture should form a part of the equipment of every cultured person. It not only illuminates his reading and his thoughts, but it doubles the interest of every journey that he takes, every town that he visits, every house that he enters. To an architect it is absolutely essential, for in studying the problems of the past he learns how to face the often totally different problems that confront him to-day. Few medical men and hardly any engineers trouble to delve into history, but the architect must

find at least part of his inspiration in the work of his predecessors, just as the lawyer bases much of his knowledge on the Codes of Justinian and Napoleon. Nevertheless, to the architect, the past may be a bad master as well as a good servant.

Age is *not* the only criterion of merit. There are some people who enjoy weeping over a ruin by moonlight though it is crumbling to pieces like a Gorgonzola cheese. They love the lichen and the owls, the ivy thrusting the mortar out of the walls, everything indeed but the architecture. If there is some proposal to stay the progress of decay, to strip the deadly creepers from the walls, to prevent the insidious ravages of frost, then these maudlin sentimentalists raise a howl of protest against such sacrilege. And if some fairy wand could restore in a night the abbeys of Tintern or Fountains to their former state of undamaged splendour, then the few visitors who would come to see them would be those who prefer architecture to mildew.[1] The true artist regrets that the Venus of Milo has lost her arms and nose, that the Winged Victory of Samothrace is but a fragment of her former lovely self. Did he not, he would wish to obliterate the features of Raphael's Madonnas and slash the canvases of Velasquez, merely because their unblemished perfection annoyed him. The condition of Leonardo's 'Last Supper' at Milan is an

[1] But actually 'sham' ruins have been manufactured for centuries, and Anatole France describes in *Thaïs*, presumably with some justification from history, 'a ruined colonnade and imitation rocks' in the garden of that famous courtesan in Alexandria during Roman times. Thus the worship of mere ruin, though essentially unhealthy, is no novelty. A sixteenth-century example of a 'sham' ruin is cited by Vasari (IV, p. 404, in *Bohn's Library*).

example for the admirer of decay to gloat over, but to the rest of the world it is a tragedy.

Yet, though there is no intrinsic merit in the merely antique, there is a very real charm that accrues to a good building with the passage of time. Hard lines lose their hardness, bricks and tiles and masonry assume a mellower tone. And, though we need not assume that a work of architecture must be completely covered with creepers to become beautiful, there are few buildings in this country that are not enhanced by a setting of ordered gardens and venerable trees.

Part of that charm, at any rate, is due to the discriminating selection of materials and to the craftsmanship with which they are handled. This is an aspect of architecture which is liable to be overlooked by a visitor to a great cathedral. He is so much impressed by the grandeur of the whole vast edifice, the profusion of carving, and the glow of stained glass, that he is apt to allow his critical faculty to be swamped by a flood of admiration. The history of our cathedrals forms a noble and inspiring theme, but we of to-day can find more that will help us by tracing through the ages the crafts that are still practised among us, often with surprisingly little change.

In this study, the very last object to be aimed at is blind imitation. As subsequent chapters will show, the free use of ' copybooks ' by architects in the eighteenth century gradually killed the traditional crafts, and the nineteenth century is seriously described in histories of architecture as the ' Age of Revivals ', which came one after another in a sordid procession. The builders of bygone times never rejected anything because it was

new, and they hardly ever copied older work directly till the eighteenth century. A Tudor craftsman who aped either the manners or methods of his Norman forefathers would be regarded in his own day as a lunatic. And when the fifteenth-century masons succeeded in building their first fan-vault one may imagine that they boasted of the novelty of their invention; they would not try to justify it by a reference to the tradition of the Normans. Their minds were receptive rather than retrospective.

In the study of old building crafts, then, we need not have as our goal their revival at the present day. The cult of ingle-nooks and warming-pans that followed the Gothic Revival is slowly dying, and the modern housewife is more concerned with labour-saving than with imaginary quaintness. But we have lost something that the Middle Ages and the village craftsmen certainly had, a joy in the excellence and beauty of one's handiwork, however simple and utilitarian it be. We cannot expect to bring back the old conditions, as some cranks still hope to do. The vast industrial system of to-day, based at present too much on a league of class against class, is unsatisfactory to every humane and liberal-minded man. But it cannot be changed by a wave of a magician's wand. The artisan in the Middle Ages led a very simple life, in some ways more free than it would be in this century, but in other respects far less fortunate. He was able to take a keener personal interest in his work partly because it was definitely hand-work, partly because a larger share of initiative was allowed to him in determining its form. He was, in fact, something of a creative artist even if he were

fashioning an iron bar or glazing a leaded window, because it was assumed that he knew his craft sufficiently to do the work 'in the best manner', as the architect says in his specification. But he was not an artist in the modern sense of being a long-haired *poseur* with ridiculous clothes and eccentric morals. He was a bread-and-butter worker, who toiled long hours and often received little pay. And, above all, he was a sane and reasonable man. Perhaps, on the whole, he was less hustled than a modern architect is; but neither the bricklayer nor the plumber of to-day has a reputation for hustling. Moreover, the men of the past had fewer temptations to play tricks with material, because their choice of materials was limited.

Two factors have emerged since those days to alter conditions fundamentally and finally: machinery, and the professional architect. Many futile tears are still shed about the former, but, in spite of all leagues and associations that may be formed to arrest its progress, we all know very well that mechanical aids to work will increase every year, and that the individuality of the craftsman will sink more and more into the background unless some means can be found of making his work interesting from a mechanical point of view. A man whose sole duty in life is to reverse a lever at stated intervals cannot be expected to feel the thrill of the creative artist, but, fortunately, the building crafts are not yet entirely revolutionized by machinery, and a large part of the work involved does allow some scope to the craftsman. The purpose of the following chapters is to convince him of the dignity of his calling as well as its antiquity, of the part that it has played in the history

of architecture as a whole, and of the enterprising spirit in which his forbears met difficulties and welcomed innovations. So even the plumber and the plasterer, whose work is seldom regarded by the crowd as of any real dignity, may realize that they have a long line of great artists as their ancestors.

Just as machinery is a necessary concomitant of modern civilization, so is the architect—or some substitute—a necessary factor in modern building. He may be, and often is, an extremely bad architect, but that is because his profession is not yet closed, so that the public is at the mercy of quacks, and is often unable to distinguish between the wheat and the chaff. But the day of the master-mason is over. The modern architect must be, to a large extent, a sedentary worker. He must spend a great part of his time at his desk, near his telephone, and only a proportion of it on his buildings. On any important commission he has to employ a clerk-of-works, a man less highly trained intellectually than himself, but experienced in all the crafts that go to make a building. The danger in this delegation of duties lies in the possibility of the architect losing touch with the craftsmen and becoming a mere draughtsman. In the eighteenth century, as is explained later in this chapter, and as nearly every subsequent chapter of this book goes to prove, the architect was too often a toady and a pedant, the hireling of princes and profiteers. He published albums of his designs, introduced by a sycophantic dedication to some noble patron. He was alternately a cringing worm and a blustering cheapjack. The day of such things is now over, or nearly so, but the damage was done irrevocably, and the modern

architect has to live down the reputation that his great-grandfathers made for him.

It is a mistake to think that there were no architects in the great periods of the past. They may have worked under another name, and their functions naturally differed in some respects from ours to-day, but it is abundantly proven that none of the great buildings in history could have been erected without the control of some master mind. Great art cannot be produced by a committee, nor could anything so complex as the Parthenon or Salisbury Cathedral have leapt from the ground at the behest of a handful of rustic masons.

But the architect of to-day must be the master-builder as well as a draughtsman. Only so can the craftsmanship be worthy of his original design for the building, and, conversely, only thus can the design be worthy of the craftsmanship. There has been a tendency in some schools of architecture to stress unduly the value of mere draughtsmanship. Although modern architectural drawing has reached a wonderfully high standard, and although it is invaluable to the architect in after-life, he should be constantly reminded in student-days that his primary function is to *create* good buildings, and that it is only by this means that he becomes an architect. We do not remember Ictinus, or Bramante, or Wren chiefly for their drawings, though they did draw, but for their masterpieces in stone.

There is no divorce between architectural design and ' building-construction '—as is too often imagined in the schools—and no ' eternal triangle ' of design, tradition, and construction. Modern construction, as this book will show, is based upon tradition ; modern design also

is admittedly based upon tradition, perhaps too much so, and should be equally based on construction, as it nearly always was in the past. The three factors form an inseparable whole, and good architecture of all periods —old and new—is simply a glorification of good building, in which architect and craftsmen alike have played a worthy part.

Some writers have misrepresented the architect, denying him his due in the Middle Ages, and ascribing all credit to the craftsmen. In this little volume, although much of the blame for smothering the individuality of the English craftsman in the eighteenth century is attributed to certain architects of that period, an endeavour is made to preserve an impartial attitude to both classes of workers. And before proceeding to consider the several crafts in detail, chapter by chapter, we may take a brief survey of the conditions under which building was practised during the chief periods of architectural activity, noting especially the relation of the craftsman to the architect, master-mason, or whatever the directing functionary was then called.

. . . . . .

The craftsmanship of Ancient Egypt inevitably occupies a prominent place in nearly all the subsequent chapters of this book. Not only was it the first of which we have any accurate knowledge, but it reached a level of skill and taste that was not surpassed for centuries and in some directions has never been rivalled. Yet to many people the delight of studying the artistic triumphs of this remote age is marred by the consciousness that it was only achieved by a prodigal waste of human energy and life. Frescoes and bas-reliefs depict

countless hordes of men straining under the lash, and a little imagination enables us to fill in the blanks—a burning sun, clouds of parching dust, the interminable monotony and cruelty of it all. A famous painting by Sir Edward Poynter, 'Israel in Egypt', has pictured a typical instance. A colossal stone lion is being dragged through an Egyptian street by teams of bending slaves. Overseers with whips stand on the clumsy dray bearing the colossus, and another overseer prods with a spear one man who has 'fallen by the wayside' and to whom a woman is offering a drink of water. Behind the lion rides the king in his litter, sheltered by an umbrella from the blazing sun that beats on the unprotected heads of the sweating slaves. The Egyptians, like the Assyrians, seem to have delighted in mere vastness for its own sake, and, though ingenious theories have been propounded as to the various mechanical means that may have been adopted to reduce labour, it is quite certain that practically all this enormous output of work was obtained by an incredible expenditure of man-power.

Granite is the most obstinate of all natural building materials, but it was used freely in Egypt. Obelisks of huge size were transported hundreds of miles and erected somehow, yet when one of them was re-erected in Rome in the sixteenth century it was counted an almost miraculous achievement and a whole book was written about it.[1] Pyramids, that are in reality monuments of iniquity, were raised by each successive king in a vain attempt to protect his corpse from robbers. Great tombs were laboriously chiselled out of the solid rock. We of to-day have seen human lives squandered on a scale

[1] Fontana, D., *Della transp. dell. Obelisc. Vatican.* (Rome, 1590).

unprecedented in history, yet even we can grieve for some of the heartless megalomania that characterized an artistic and highly civilized people long ago.

But this is only one side of the picture; many eminent Egyptologists, among them Sir Flinders Petrie, take a very different view.

'Much nonsense has been written', he says,[1] 'about the oppression of the people, their tears and groans. With the splendid organization evident in the work, the people must have been well managed, and there was no hardship whatever in carrying out the work. Each man might be levied twice in his lifetime; he would be just as well off there as at home, for he could do nothing during the inundation [of the Nile]. All that was necessary was to transport a couple of hundredweight of food with him, which he would eat there instead of at home. The immense gain to the people was the education in combined work and technical training.'

(In this statement he does not include the vast armies of slaves captured in war, of whom Rameses III alone provided 113,433 for the godly task of temple-building.)[2] The *corvée*, or levy of men for public works, was a feature of Egyptian life that must be explained partly by local circumstances and not judged by modern standards. A great amount of repair-work to the dykes was necessitated at a time when labour on the fields was prevented owing to the inundation. This was an annual national emergency, but the prosperity of every man in the country depended on the maintenance of the dykes. So, too, after the spring crops had been gathered, there was a dead period of about three months on the farms,

[1] Flinders Petrie, Sir W. M., *Social Life in Egypt*, pp. 26–7.
[2] *Ibid.*, p. 24.

when there was no work to be done and no wages to be earned. The British administration, always inclined to be idealist and humane, abolished the *corvée*, but Professor Petrie regards this as a mistake. For, he says, the work on the dykes still has to be done, and the present system of paying for it is cumbrous and entails useless administrative expense.[1]

A modern democrat will, however, draw a distinction between works of pure utility (such as the repair of the dykes) and great monuments like the Pyramids. These, he will contend, were luxuries rather than sheer necessities. But is not the fairest comparison to be made between the Egyptian serf (who laboured for stated periods only at a time when he would otherwise have been unemployed) and such products of our modern civilization as the worker in a coal-mine, the stoker on a battleship, or the conscript in the trenches? Was the Egyptian system so very inferior to our own?

The skilled artisans in Egypt must also have been very numerous. Professor Petrie estimates[2] that the barracks at the Great Pyramid provided accommodation for a maximum of 4,000 masons who were employed on the facing of the stone blocks alone. There was usually a foreman for every ten unskilled labourers. Something in the nature of guild organization seems to have been established, for skilled workers were not allowed to change their occupation for fear of losing proficiency. But most of the skilled craftsmen appear to have been attached to the establishments of the king or of the great nobles, by whom all building of any impor-

[1] Flinders Petrie, Sir W. M., *Social Life in Egypt*, p. 23.
[2] *Ibid.*, p. 26.

tance was carried out. The chief architect (at one time styled the ' royal axe-man '), who designed and carried out the pyramids and temples, was one of the principal personages at the king's court. Professor Capart [1] explains the conventions employed by the Egyptians in architectural drawing, but does not say whether such plans were drawn before the building was erected or made afterwards as a record. Provided that they could draw, one may surely assume that architects would prepare sketch-designs for the approval of their royal masters before proceeding with the building.

The conditions prevailing in Assyria must have resembled those just described in Egypt, for slave labour was as prodigally used, megalomania was as rampant, and irrigation was nearly as vital in Mesopotamia as in the valley of the Nile. Assyrian bas-reliefs show the same crowds of whip-driven men hauling great loads. The kings were the chief builders, and an inscription of Sennacherib states, ' According to my heart's desire I built a palace of alabaster and cedar.' In Assyria, as in Egypt, there may have been extenuating circumstances of time and place, but to most of us who study these carven records of despotism and cruelty there comes a feeling of thankfulness that we do not live in those ' good old times '.

Even in the golden age of Greece the condition of the worker appears to have been far from ideal. There was culture and refinement in the Athenian state, but slaves formed a large proportion of the population. Manual labour was considered to be beneath the dignity of the citizens. Plutarch implies that free men were found

[1] Capart, J., *Egyptian Art*, pp. 145–8.

among the workers, but on the other hand it is recorded that architects and engineers were found among the slaves. There must have been among such slaves many highly trained craftsmen, for the very perfection of a building like the Parthenon indicates a high degree of manual skill as well as a profound artistic and scientific knowledge in its designers. It also involves a great deal of patient and monotonous labour, e. g., in rubbing and polishing marble to a mathematically exact surface. Man-power was not wasted in Athens to the extent that it was in Egypt and Mesopotamia, because the Greek notion of beauty was in no way identified with mere bigness. In that respect there is a definite advance on earlier periods. Yet the Greek mason cannot have had any real joy in his work such as the Greek sculptor felt. He was always working to rules of unsurpassed strictness, and his individuality had little play. He was spared a certain amount of useless drudgery, because the Greeks, as a seafaring nation, had invented various forms of tackle and other appliances that economized manual work in handling blocks of stone. The stone they used was hard, but not so hard as Egyptian granite, and they employed tools that were an advance on Egyptian types. The architect was a recognized functionary, for his name has been preserved in many cases. Thus we know that Ictinus designed the Parthenon (about which he wrote a book mentioned by Vitruvius but since lost) and the Temple of Apollo at Bassae ; that he was assisted at the Parthenon by one Callicrates ; and that Mnesicles designed the Propylaea. We may also surmise that architects such as these were highly educated and even learned men, thoroughly

grounded in science and mathematics as well as in art and construction.

The great buildings of Imperial Rome were mainly erected by forced labour. Choisy[1] states that most large buildings of the period consisted of two parts, the carcase and the facing (see Chapter III of this book). The former was almost entirely unskilled work, so could be handed over to gangs of labourers working under supervision. These gangs consisted of slaves (often captives from a war) of free men conscripted under a system of *corvée*, or even of soldiers between campaigns. (It is said that work of this sort was actually invented to keep soldiers employed.) The facing and decorative work was carried out by a higher class of workmen, who might be either free men or slaves, and who formed themselves into free societies (*Collegia*), resembling the later guilds. Curiously enough, slaves were eligible for membership of the *Collegia*, which eventually became uncomfortably powerful in the State. Under Hadrian they were recognized, they became part of the great machine, and thereafter their members were subject to a discipline nearly as harsh as slavery itself. Membership ceased to be optional or temporary; a workman had to follow his trade all his life, and his descendants after him; his rate of wages was fixed; and he could be transferred from one place to another like a parcel of goods. The craftsmen were thus brought into the vast administrative organization that really constituted the Roman Empire, and the surviving skeletons of their greatest works—the baths, the amphitheatres, and the aqueducts—now mostly stripped of their marble or stone

[1] *L'art de bâtir chez les Romains*, p. 199.

facings, all seem to bear the powerful and uniform stamp of military engineering upon them.

The Roman architect, too, was an official, and, considering the amount of literature that his age has bequeathed to us, we know singularly little about him. It is a question whether Vitruvius can be regarded as typical of his time. He is frequently quoted in later chapters of this volume, but that is because his famous book on architecture is the only one that has survived to us from the distant past. He is not even a great writer, and his efforts at literary style in the introductions to his ten 'Books' remind one of the vulgar and fulsome dedications of English architect-writers of the eighteenth century. But he has told us much that is useful of architecture and building as it was practised in his day (generally believed to be the Augustan Age), and in the introduction to his Book I he tells us what he considers the qualifications of the architect should be.

'Let him be educated, skilful with the pencil, instructed in geometry, know much history, have followed the philosophers with attention, understand music, have some knowledge of medicine, know the opinions of the jurists, and be acquainted with astronomy and the theory of the heavens.'

Of conditions among building workers in the sixth century, when the capital of the Roman world had been moved from Rome to Constantinople, Gibbon wrote: 'The edifices of Justinian were cemented with the blood and treasure of his people.' Recent writers, however, do not altogether support this assertion, and one of them [1]

[1] T. S. Attlee, 'The Influence on Architecture of the Condition of the Worker', *R.I.B.A. Journal*, 1914.

goes so far as to assert that 'In Constantinople in the time of Justinian we find the beginnings of Freedom and of Association among the workers'. Choisy has pointed out [1] that the Roman *Collegia* survived under the Byzantine Empire, but under changed conditions. On the one hand the oppressive restrictions tying the members to the State were removed, while on the other hand their immunities and privileges were increased. The individual craftsman was still by no means free in the modern sense. Military labour was still employed on buildings and the *corvée* was not abolished. But things were improving, and the character of the guilds became more democratic.

'They were at once craft-guilds, religious confraternities and benefit societies, but the most notable fact about them is that not only the skilled trades were organized, not only the aristocracy of labour, but unskilled workers, labourers, and porters. . . . Choisy states, too, that everywhere in the East now work is done by a master-worker and his body of fellow workers, who carry out the work together, each performing every sort of task, rough and smooth, construction and ornament, and he gives the organization of the workmen's guilds in the East to-day which have changed very little, if at all, from the ancient organization of the Byzantine Empire. "The workman", he sums up, "is no mere passive instrument, obedient without any regard to initiative or responsibility to the workshop foreman: he is treated as an intelligent power, and finds in front of him liberty and a field open to his imagination." . . . The workmen's organizations, moreover, took part in local government: we can see the beginning of that organization of municipalities on the basis of the guilds, which is the distinctive feature of medieval town life.

[1] A. Choisy, *L'art de bâtir chez les Byzantins*, pp. 176–7.

It was the duty of the guild members, for instance, on the cry "Omnes Collegiati" to gather to help to put out fires in the city.' [1]

'The crafts occupied fixed quarters in the city: all products had to be sold in open market at a standard price: the corporation usually bought materials in block, which it distributed among the members of its College; but in the regulations referring to the Building Crafts . . . we find that it was customary for the employer to furnish materials and for the craftsmen to engage to do the work.' [2]

The result of these improved conditions is to be seen in the originality and inventiveness displayed in Byzantine architecture. The direction of the works must have involved some master mind, and, in the case of St. Sophia at least, the names of the two architects are known.[3] It goes without saying that they must have been great artists and daring constructors. Justinian himself took a keen interest in the progress of the building, and by providing a series of convenient miracles at crucial stages in the work he was of definite use.

The Saracenic craftsmen of medieval Cairo are frequently mentioned in later chapters of this book, but legend and fact are difficult to separate in the chronicles of their labours. Two stories of an architect's adventures under Ibn Tulun, a ninth-century governor of Cairo, may be quoted.

'When the amir (governor) was informed that 300 columns would be required for the new mosque if the ordinary method of construction was adopted, and that this would involve the destruction of a large number of

[1] T. S. Attlee, *op. cit.*

[2] W. R. Lethaby, *Medieval Art*, p. 65.

[3] T. G. Jackson, *Byzantine and Romanesque Architecture*, i, p. 82.

provincial churches, he was very much troubled and declined to authorize the work. This difficulty came to the ears of . . . the unfortunate architect of the aqueduct, who was still languishing in prison. . . . The imprisoned architect saw in the amir's dilemma a chance of release. He wrote to Ibn Tulun and undertook to build him a mosque of the requisite size without employing a single column except the usual pair flanking the *mihrab*. He was brought before the governor and offered to draw a plan for him on the spot, if parchment could be brought to him. Ibn Tulun was surprised and delighted with the result, released the architect immediately, arrayed him in a rich robe, and paid him the sum of 100,000 dinars (over £50,000) to enable him to commence operations at once. Should any architect feel disposed to envy the Copt's good fortune, it should be explained that he was master-builder as well as architect, so that this large sum of money was not by any means a fee for the design but a payment on account of the building. And at the price of a preliminary imprisonment to satisfy the whim of a cruel despot, it does not appear that the lot of a professional man in the ninth century was a happy one.' [1]

' It is said that one day Ibn Tulun was thoughtlessly toying with a piece of paper in the presence of his architect, that he was suddenly conscious of being observed in an act of frivolity ill-befitting so stern a monarch, and that he thereupon ordered the architect to take the spiral form that the paper had assumed in his hands as a model for the new minaret of his mosque. There is probably no truth in the story, but it goes to prove that the forceful amir must have been a great trial to his professional advisers.' [2]

At a later date Armenian masons, renowned for their knowledge of stereotomy, were brought to Cairo, and

[1] M. S. Briggs, *Muhammadan Architecture in Egypt and Palestine*, p. 51.

[2] *Ibid.*, p. 56.

during the Crusades Eastern and Western ideas of building often changed hands. The greatest buildings in Cairo were erected between the thirteenth and sixteenth centuries, and some writers relate that mosques and hospitals were erected by workmen under the lash of an amir or foreman who stood on a ladder whence he could survey the whole site.[1] But the extraordinary beauty, delicacy, and fantasy of these buildings and all their accessories does not suggest a whip-driven slavery such as the Pharaohs used, but rather the patience of an unhurried artist who had a real love for his work. Something is known of the functions of a medieval architect in Cairo,[2] but the uncertainty of his position is revealed by another story of the mosque of Sultan Hasan.

'It was typical of the spirit of the age that the sultan was so delighted with the building when it approached completion that he cut off the architect's hand lest that unfortunate official should ever produce a more beautiful monument to rival it.'[3]

Returning to Europe at the beginning of the Middle Ages, we find Byzantine influence radiating westwards across Italy through countries where the Lombard style was rising from the ruins of Roman civilization. A knowledge of art was disseminated by small portable objects rather than by craftsmen themselves among people who were almost barbarians, and the efforts of early Christian church-builders in our own islands have been likened to the modern missionary's attempts to teach carpentry to the woolly-haired denizens of the tropics. Learned priests brought plans and ideas from

[1] M. S. Briggs, *Muhammadan Architecture in Egypt and Palestine*, pp. 89, 92. [2] *Ibid.*, p. 93. [3] *Ibid.*, p. 107.

Lombardy, but, as Professor Prior has aptly said, ' Craft cannot travel in a schoolman's baggage '.[1] (The truth of this aphorism, more especially in regard to the eighteenth century, is amply confirmed in later chapters of this book.)

If we pass by the question of the Comacine masters, about which whole volumes have been written and many tempers lost, we come to the next stage in the history of the building crafts with the rise of monachism in Western Europe. Scholars are in disagreement as to many aspects of monastic life, but they agree on the main point of interest to us here, that the rapid development of building in Western Europe during the eleventh and twelfth centuries was almost entirely due to the activity of the Benedictine and other monastic orders. The rule of St. Benedict not only encouraged manual work but enjoined it as a duty. ' Laziness ', he said, ' is the enemy of the soul, and consequently the brothers should at certain times occupy themselves in manual labour ; at others in holy reading.' [2] And, moreover, they were forced to rely on themselves to produce all such buildings as they needed. Guilds of artisans existed in Italy, but not in France or England, where craft-tradition had been almost lost since Roman days. ' The inmates of the convents had to be their own builders, masons, carpenters, glaziers, and to fulfil every function of the building trades.' [3] Their churches and conventual buildings were of immense size, demanding a greater knowledge of construction and a wider skill in crafts-

[1] E. S. Prior, *English Medieval Art*, p. 14.
[2] Guizot, *Civilization in France*, Lecture XIV.
[3] T. G. Jackson, *Byzantine and Romanesque Architecture*, ii, p. 93.

manship than any village artisan could have then possessed. The difficult science of vaulting was slowly developed by experimental methods, successive attempts being made to lighten the structure and to concentrate the weight of a fireproof stone-vaulted roof at fixed points. But, though this organization was institutional rather than popular, such enthusiasm occasionally prevailed that rich and poor alike offered willing service to the monks. Thus, it is told of an abbey in Normandy how 'Tyrants, Lay Potentates full of honours and riches, Nobles both men and women, bent their proud and swelling necks to the traces of waggons laden with wine, corn, oil, lime, stone, timber, and other things useful for victuals or for construction of churches, and drew them to the shrine of Christ like brute beasts'.[1] (There is almost a hint of 'class-feeling' in this edifying picture.)

The directing mind in monastery-building (*cementarius*, *ingeniator*, *lathomus*, or whatever he is called in contemporary records) is a somewhat shadowy personage. William of Sens, who began the rebuilding of Canterbury in 1174, was a Frenchman. He designed the cranes for transferring Caen stone from ship to barge at Richborough; he supplied details of stone mouldings, and directed all the work of the masons. It is important to note that he was brought to England from abroad as an expert, and it is difficult to deny him any glory there may be in the modern title of 'architect'. Further reference to the status of the master-mason will be made shortly; at the moment it is enough to say that William of Sens is not by any means an isolated example of his class.

[1] Quoted in T. G. Jackson, *Gothic Architecture*, ii, p. 306.

The end of the thirteenth century marks the transition from Romanesque to Gothic architecture, a change that was accompanied by other changes in the organization of building, which henceforth ceased to be practically a monopoly of the monastic orders. We may therefore consider briefly how Gothic building was carried on, under what conditions the craftsmen worked, and by whom they were directed. The popular superstition seems to be that our cathedrals leapt heavenwards from the hands of simple but inspired rustics, who were subject to no control save the benignant voice of a mitred abbot, and were oblivious of such mundane details as food, hours of work, wages, or holidays. The complex ribs and shafts of the vaulting rose easily and naturally like the trees of the forest, blossoming out at intervals into carved foliage of unsurpassed beauty.

Without denying the attraction of this idyllic picture, it must be remarked that no buildings so elaborate in form and decoration could have been so erected; and that the masons of old were men of like passions with ourselves, difficult to handle at times, and beset with problems such as we have to face to-day. Conditions were different in building as in every department of life, but human nature was the same.

The medieval craftsman worked very long hours, usually from sunrise to sunset, with certain intervals, e. g., at York Minster in the fourteenth century, twenty minutes for breakfast, an hour for dinner (followed by an extra half-hour for a nap in the summer), and a few minutes for a drink in the late afternoon.[1] A church bell took the place of the foreman's whistle. No work

[1] L. F. Salzman, *Medieval English Industries*, p. 117.

was done on saints' days, but these were so numerous that wages were only paid for half of them. Wages were higher for the long summer days than in winter, typical figures for the fourteenth century being 5*d.* and 4*d.* per day respectively.[1] Building in frosty or very wet weather was as impossible in the Middle Ages as it is to-day, and this fact must have caused as much unemployment and misery among masons and bricklayers as it does now. A comparison of prices then prevailing is very difficult and in any case is far beyond the scope of this book. The monumental work of Professor Thorold Rogers [2] contains much valuable information about wages and prices in the building trade. But the uncertainty of determining an accurate 'cost of living figure' makes comparison almost impossible. Wages varied greatly, not only at different periods, but simultaneously in different trades and districts. Thus quarrymen at Tadcaster were receiving 1*s.* 4*d.* a week in 1333, while skilled masons there earned 2*s.* 6*d.* and their foreman 3*s.* At another quarry in 1296 stonebreakers received 1½*d.* to 2*d.* a day, and the women who carried the stone received 1*d.* a day.[3] Even with a most generous allowance for rise in prices, one cannot see much reason for modern workmen to sigh for 'the good old times'.

Nor was there unlimited freedom for the artisan. He was fined for being late, for idling, quarrelling, losing his tools, and obstructing other workmen. But at times he adopted tactics that are regarded as essentially

[1] L. F. Salzman, *Medieval English Industries*, p. 118.
[2] J. Thorold Rogers, *A History of Agriculture and Prices.*
[3] Salzman, *op. cit.*, p. 90, quoting original authorities.

modern. Thus Wyclif says of certain masons that they ' conspire together that no man of their craft shall take less for a day than they fix, though he should by good conscience take much less—that none of them shall do good steady work which might interfere with other men of the craft, and that none of them shall do anything but cut stone, though he might profit his master twenty pounds by one day's work by laying a wall, without harm to himself '.[1]

But trade combination was most apparent in the remarkable system of guilds that grew up early in the Middle Ages in England and elsewhere, and that played so prominent a part in the advancement of good craftsmanship. The guild idea, as applied to crafts, may have come from Constantinople, where their existence has been noted above, but it is a vexed question on which we need not enter here. Curiously enough, there seems to be some doubt as to whether a guild of masons existed in England.

' Rules for the mason's craft were drawn up in London in 1356. Of these the most interesting is one which provides for a guarantee of ability and joint responsibility for contracts: any one undertaking a contract was to come before the good man for whom he was going to work, with four or six experienced masons who should swear that he was capable of doing the job and that if he failed they would themselves complete the work on the same terms. There was no regular gild with wardens and other officers, so masters were elected whenever building operations were in progress to see that the work was properly done, and that the workmen were paid according to their deserts and not outrageously —for complaints of the extortionate wages demanded

[1] G. G. Coulton, *Social Life in Britain*, p. 491.

by masons were frequent, and they seem to have been more successful than most crafts in obtaining higher rates of pay. These rules of 1356 were compiled by a commission of six mason hewers and six mason setters. The setters, wallers, or layers, were those who built walls and did other work of what we may call solid masonry ; the hewers are more usually called free masons, from their working free stone (*i. e.* blocks of stone shaped or carved separately, such as arch mouldings, window tracery, and so forth). The constant use of the term free mason led, as so often in folk-etymology, to the invention of a legendary origin for it, and the free mason became in popular imagination possessed of mysterious privileges of freedom derived from Euclid, Solomon, or Adam.' [1]

Professor Lethaby, on the other hand, speaks of a Masons' Guild, in which 'mastership was closely parallel to that of a master of arts in the university, that is, the Guild of Letters. By serving a seven-years apprenticeship he became a bachelor or companion, and, on presenting a proper work-thesis, he was admitted master. Our curious courtesy title, "Mr.", does not mean employer, but graduate of guild ; however the two meanings came together, as only a master might be an employer.' [2]

Several of the building-craft guilds of London still survive in the City Companies (of which the Carpenters' is perhaps the best known), and they continue to maintain the training of craftsmen at their trades-school in Great Titchfield Street.

The masons, especially, moved from place to place on the larger buildings. Thus at Westminster there were as

[1] Salzman, *op. cit.*, pp. 114–15.
[2] Lethaby, *Medieval Art*, p. 255.

many as 700 employed when Henry III was hustling the work so that it should be completed on the ' opening day ' that he had decided on, and on the Round Tower at Windsor 720 men were employed in one week in 1344.[1] Travelling craftsmen of this sort were regarded as foreigners by the local artisans, but for the smaller crafts local labour could often be utilized.

Transport was an important problem when roads were practically non-existent and everything had to be carried on pack-animals. Water-transport was employed whenever possible, and it was often as easy to bring the fine Caen stone across the Channel as to convey English stone overland from a distant quarry. Where pack-transport was the only means available and no quarry was near at hand, the result was often the use of small blocks of stone and a consequent change in methods of design. Medieval scaffolding closely resembled its modern counterpart, but the platforms were generally formed of hurdles.[2] Hanging ' cradles ' were used then, as now, by plumbers and glaziers doing repair work,[3] while windlasses and other apparatus formed part of the builder's stock-in-trade. The ' builder ' was, however, none other than the master-mason himself, who thus combined the triple function of architect, builder, and clerk-of-works. With a short study of his work this summary of medieval building is concluded.

The earliest use of the word ' architect ' is said to be in the year 1563,[4] but the functionary who occupied his place in the Middle Ages held the same position, in the

[1] Salzman, *op. cit.*, p. 116.
[2] *Ibid.*, p. 124, with illustration.
[3] *Ibid.*, p. 125.
[4] *Ibid.*, p. 103.

sense that he designed buildings and supervised their erection, which, after all, is precisely the main work of a modern architect. Often he resided on his work, and was thus the exact equivalent of the modern 'resident architect' stationed on large buildings. But this was not a universal rule, and there are many medieval instances of architects who were non-resident and had several buildings in hand at once. He drew plans on paper; indeed without such plans no great cathedral could have been erected. Somewhere near the building in progress was his drawing-office, or 'trasour', or 'tracyng house', where he prepared plans and detail drawings.[1] He also prepared estimates of the cost and a detailed specification on which the contract was based.[2] Models are often mentioned in old documents in Italy and elsewhere abroad, but do not seem to have been used much in this country.

Behind the architect was frequently a 'Treasurer' or 'Surveyor' who dealt with matters of finance and was therefore to some extent his 'client' or employer. But the chief difference between the medieval and the modern architect is that the former was trained primarily as a mason and not as a professional man in an office or a school. Much has been made of this distinction, but in fact it is only a difference of time and circumstances. A medieval building of any size was more than three parts masons' work. Plumbing, slating, glazing, and even carpentry were only accessories to the main structure. The architect had to know masonry above all the crafts, and it was the most difficult of them to understand, for every important structural problem

[1] Salzman, *op. cit.*, p. 116. [2] *Ibid.*, p. 121.

involved in the building—the thrust of the vault, the counterpoise of the buttresses, the design of the tracery, the interpenetration of the mouldings—was a masonry problem. In an age when there were no text-books to speak of, knowledge of such intricate questions of mechanics and geometry could only be acquired by experience based on the experiments of others.

It has been said that another difference between old and modern practice lay in the fact that the master-mason and the master-carpenter each prepared plans for their respective parts of the work.[1] It would be a fairer comparison to state that the master-mason (or architect), after making the main design for the building himself, assigned the detail drawings of the roof and other wooden features to the master-carpenter, just as a modern architect, after making the main design for the whole building himself, might assign the detail drawings of its roof and doors to his assistant or draughtsman.

The medieval architect often added to his experience by travelling and sketching abroad. In the sketch-book of Wilars d'Honecort (or Villard de Honnecourt), a French architect of the thirteenth century, we have a priceless witness of this fact. Indeed this little leather-bound book, preserved in the Bibliothèque Nationale at Paris, is one of the most valuable relics of the Middle Ages. Thirty-three of its original leaves remain, and on them are drawn 63 subjects, of which 35 represent figures and grotesques, 16 plans and details of architecture, 5 details of carpentry and masonry and geometry, and the remainder are miscellaneous. They form

[1] *Ibid.*, p. 112.

records of extensive travels in France, Germany, Switzerland, and Hungary, and in some cases are very obviously sketches of features that seemed to him likely to ' come in useful ' in his practice at home. They prove, first of all, that he was an excellent draughtsman, not only of masonry details as one would expect, but of the human figure and of ornamental work. There is a beautiful freehand sketch of a carved wooden bench-end that the most skilful modern draughtsman might be proud to own. The plans of cathedrals show all the lines of the vaulting besides the walls and windows. Some of the diagrams of masonry display an intimate knowledge of geometry, and notes in writing on some of the plans indicate quite clearly that he was studying architecture and ornament with a view to utilizing it for buildings on which he was either actually engaged or hoped to be engaged. It proves without doubt that the only medieval architect of whom we have so full a record was an accomplished draughtsman, a traveller, a student, and a man of wide artistic sympathies, in addition to being a competent master of stonecraft. It establishes the fact that the master-mason of the Middle Ages was the counterpart of the professional architect of to-day.

For the rest, it may be added that the master-mason seems to have been a person of some consequence, wearing a robe of office if engaged on the royal service, and well remunerated. (Arnolfo del Cambio was excused his income-tax in Florence in 1300 as a special privilege.) It has often been said that his work was always anonymous, but this is not strictly correct. Many instances are known of prominent inscriptions on medieval buildings recording the names of their designers, and at

Caudebec there is a gravestone bearing the master-mason's effigy, a ground-plan of the church, a pair of compasses, and an inscription. Very often the abbot or bishop caused his name to be carved on the building as the person who had done the work, and the monkish historians seldom troubled to perpetuate the memory of a mere layman. But is not this state of affairs strangely matched in our own day, when at the opening of some great public building a crowd of pompous nobodies throngs the portal, and if the designer's name leaks out into the press it is probably obscured by a photograph of the Alderman's youngest presenting a bouquet to Her Royal Highness.

When the Renaissance dawned in Italy, the comparative anonymity of the architect ceased, but for a long time he was a master-craftsman rather than the professional and sedentary architect of to-day. Brunelleschi, like many great Italian artists, began his career as a goldsmith, having previously found the atmosphere of a lawyer's office distasteful to him. Later he went on a sketching and measuring tour to Rome, with his friend Donatello. Then came his great work in the cathedral at Florence, and thereafter it is as an architect that we hear of him. In the competition for vaulting that building, many models were submitted, and there is no record of drawings. But Brunelleschi seems to have worked from both drawings and models. On one occasion the carpenter whom he employed to make his models entered on his own account for a competition against his master. This shows how faint a line divided the craftsman from the architect proper. Indeed the whole history of the Renaissance in Italy shows a suc-

cession of brilliant geniuses, like Michelangelo and Leonardo, who were skilled in painting, sculpture, architecture, goldsmiths' work, poetry, natural science, mathematics, and military engineering; able apparently to excel in any or all of the branches of knowledge that they practised so easily. They seem to have found handwork and headwork perfectly reconcilable, and for them there was certainly no divorce between design and construction.

In France the first craftsmen of the Renaissance were mainly Italians, who began to arrive towards the end of the fifteenth century. They were imported by the king, and their work was at first what we should call decoration rather than architecture, but as time went on they were called on to design buildings. Meanwhile French craftsmen, working abreast of them at painting and carving, acquired most of the new fashions from Italy. But for some time the master-mason continued to be the chief personage connected with a building, combining the modern functions of architect and builder, drawing the plans and supervising the erection, and often possessing a builder's yard, plant and tools, and a stock of materials such as timber and stone. This was only possible so long as architecture remained traditional, for the master-mason worked more or less on standardized lines. But now that new ideas began to arrive from Italy, a learned exponent of them was necessary, and the publication of Vitruvius, probably in 1486, laid down rules for every detail of a design, cutting right across the simpler tradition that had hitherto held sway. Philibert de l'Orme (1515–70) was one of the first French professional architects. He seems to have restricted his activities to architecture (except perhaps

for a little soldiering), and had a very successful career, at the end of which he had added several sinecure and profitable ecclesiastical offices to a large salary. He also wrote books of some importance dealing with the architectural Orders and with construction. He invented a new type of built-up timber roof-truss which is still known by his name. But though the architect in France thus gradually drifted away from the craftsman, his status was not always strictly defined, and so late as 1665 we find that a design for the façade of the Louvre by Claude Perrault, a medical man who had useful friends in high places, was accepted in preference to those of professional architects.

In England the medieval organization, with the master-mason at its head, persisted even longer than in France. Sir Thomas Jackson quotes the accounts for the building of Wadham College, Oxford (1610–13), where it appears that there was no architect proper, but only a clerk-of-works or chief workman, who was paid on that basis. The first professional architect is believed to have been John Thorpe, a shadowy figure of Elizabeth's day, whose book of designs and plans is preserved in the Soane Museum. It is uncertain how many of the houses represented are his own designs, but at all events it appears that these outline plans were used for setting out the walls, that there was no specification nor quantities, and that, instead of detail drawings of every decorative or constructional feature being furnished by the architect as in modern practice, these matters were settled verbally as the work proceeded or were left to the individual initiative of the craftsman.

Of Inigo Jones (1573–1652) we have much more full

and accurate knowledge. Born in London of humble parents, he is said to have been apprenticed to a joiner. Having attracted the attention of a nobleman at Court, he was enabled to travel in Italy on a sketching tour. He then settled down as a designer of Court masques, and continued this work abreast of his architectural practice almost up to the time when the Civil War put an end to such frivolities. From 1616 until the war, and also for the last few years of his life, he enjoyed great success as an architect, his work being partly derived from his office as Surveyor-General of the Works and partly from commissions from noble patrons. He became a courtier and an aristocrat, in spite of his lowly origin, but he was a brilliant and able man with a wide knowledge of mathematics and construction as well as artistic gifts. He was quite definitely and almost exclusively an architect, though his 'second string' (in the shape of scene-painting) bears witness to his versatility, a characteristic of that marvellous age, and he did much to promote the study of Roman models that stifled the craftsman and destroyed his individuality in later days.

Sir Christopher Wren (1632–1723), though even more of a professional architect, entered on his calling from an unusual direction. His brilliant career has received so much attention during the past year (his bicentenary) that it is unnecessary to dwell upon it further than suffices to point a moral. He was a man of such commanding intellect that in any walk of life he would have risen to the top, and his success in architecture is no justification for arguing that technical training is unnecessary. He brought to his new profession a brain already highly skilled in science and mathematics, a

natural inventiveness, the hand of an expert draughtsman, and the eye of a born artist. He had influential relatives who helped him from the first: he was both enterprising and unselfish (an unusual combination), and in the Great Fire he had such an opportunity as never occurred to man before. The craftsmanship of his buildings is of the highest order, proving that in his day, at any rate, the architect had not yet lost touch with his material. It is significant that he did not publish a copybook of the classic Orders.

Almost his contemporary was one Joseph Moxon (1627–1700), like him a Fellow of the Royal Society, and an amazingly many-sided man. Born in Wakefield, he later kept a shop in Cornhill, where in 1657 he published a book on Navigation, followed in 1659 by another on Astronomy and Geography, in 1674 by a treatise on the Polar Passage, later by a manual of printing, and in 1670 by a translation of Vignola's book on architecture. But he is interesting to us chiefly for his *Mechanick Exercises, or the Doctrine of Handy-works*, which began to appear serially in monthly parts in 1678. This little manual of building-construction has been freely quoted from in the present work, for it tells us more of the building crafts in Wren's day than we could learn in any other way. It is the work of an ' amateur ', but an amateur whose bias was towards the scientific and practical aspects of building. Incidentally he explains the use of an architect's plan and elevation, of which he gives an example drawn to a scale of 7 ft. to 1 in.

But the amateurs who followed in the later years of the eighteenth century were men of a very different stamp. Books on the Orders, of monumental designs,

and even on building-construction, began to pour forth. Some of them were written by comparatively uneducated men, such as Batty Langley and William Pain, who entered architecture from the carpenter's bench. Indeed Pain subscribes himself 'Architect and Joiner' on the title-page of a book published in 1774. At the other end of the scale were such gilded dilettantes as Lord Burlington and Dean Aldrich, who regarded architecture as a suitable pastime for a gentleman's leisure. They all made the Grand Tour, and they all made the Orders their Bible. Between these two extremes was a host of more or less able professional architects, but they took their cue from their patrons, and in a highly artificial age they made architecture an affair of rules, so much so that only a pedant could understand it. At this point the craftsman became a mere tool, his functions being limited to carrying out the instructions of the learned architect. In later chapters of this book the decline of traditional crafts in the late eighteenth century is traced in detail.

Not until the advent of Ruskin and Morris led to the much-ridiculed 'Arts and Crafts Movement' of thirty years or so ago did English people begin to realize what they had lost. Recently there have been many indications that the public is beginning to appreciate the charm of good work even in little things, and architects have long been attempting to recover the spirit of the past, when the craftsman was able to put his heart into his work. The purpose of this little book will be served if it enables architect and craftsman alike to appreciate their mutual dependence, and if it inspires them both to emulate the spirit of the past rather than to make a mere copybook of it.

II

BRICKWORK

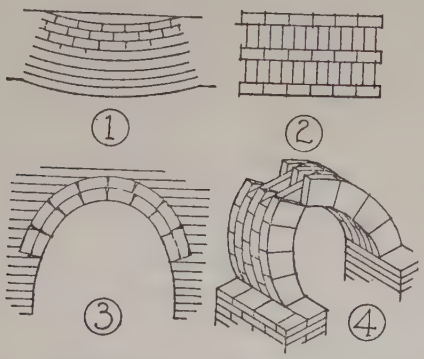
It is impossible in so short a book as this to trace the progress of rudimentary building among semi-barbarous peoples. Others have described the evolution of primitive structures of wattle and daub—not much better than the ingenious homes made by beavers and certain birds for themselves—and the rough huts of tree-trunks and moss that preceded building in stone and brick among the Northern races. In these chapters my object is to trace, one by one, the various ' trades ' or processes that are common alike to building in the past and to work of our own days. Of these ' trades ', brickwork perhaps comes first in historical sequence, as it does in a modern architect's specification.

Moreover, it appears certain that many familiar features of the very earliest masonry structures known in Ancient Egypt were derived from brick prototypes. The historical study of any elemental form of building must begin on the banks of the Nile. Here, besides the granite and limestone that came into use thousands of years ago, have always been found two materials available for building : the mud that is washed down from Central Africa in the annual inundations, and the trunks of date-palms. As we shall return to this subject, it is worth while emphasizing its importance here. In Egypt at the present day men are building hovels for themselves exactly as they did six thousand years ago. You

may see them from the windows of a dining-car in an express train ' replete with every modern convenience '. They are still being erected almost within the boundaries of great cities like Cairo and Alexandria, which boast of hotels and shops that compare with those of a European capital. And the reason is that Nile mud and date-palm trunks are still the only building materials within the reach of the very poor. Neither is particularly well suited to its purpose, and, as the date-palm provides the peasant with half the necessities of life, he naturally hesitates to fell it for use in building. So, at the outset, the Egyptians were practically limited to the use of Nile mud as a building material, and this they employed sometimes in the form of *pisé*, more commonly as sun-dried bricks. But walls are still built, as doubtless they were long ago, of blocks of mud lifted out of the ground as it cracks and dries in the heat of the sun ; and these natural blocks may have suggested the use of artificially moulded sun-baked bricks. The making of such bricks is described in the Pentateuch. Probably it puzzled most of us in our childhood to know why the lack of straw made the work so hard for the Israelites. Many of us found the explanation only a few years ago, when our Army's efforts at brick-making for incinerators and the like were hampered by quarter-masters as stern as any Pharaoh. The chopped straw used as forage for our transport-animals then was the same chopped straw that the Children of Israel needed to give toughness to their sun-dried bricks. Without it, the friable Nile mud crumbles in time. An early fresco shows brick manufacture in full swing. Clay is being brought in buckets from a heap to the moulder, under the super-

vision of an overseer. The moulder is shown at work, then the stacking of the bricks to dry, then the carrying of bricks to the bricklayer, and finally the bricklayer plumbing the newly-built wall.

No foundations, as we understand them, were used. On sites above the level of the inundations, the bottom courses of brickwork were laid direct on the levelled ground. But where the site lay, as usually, in the valley of the Nile, the walls were built concave (Fig. 1), thus



providing an extra resistance to sliding and settlement in flood-time. (At Philae, the most famous example of an island-temple, the same treatment is carried out in solid masonry.) It is possible that the familiar ' batter ' of Egyptian pylons may be derived from this, or from *pisé* construction. Piling was often used in treacherous or flooded ground.

The main structure of the wall was of sun-dried bricks, built in some sort of bond. Fig. 2 shows a typical bit of Egyptian bonding, and it is worth noting that a common form was what we now call ' English Bond '.

The size of the bricks varied greatly, but as a rule they were at least 4 in. thick, and the width was half the length. Generally speaking, the size increased from the fifth to the seventeenth dynasties, and decreased after the twenty-first. The makers' marks on them show that they must have been dried in the sun after moulding and before laying, whereas in Assyria they were laid while still moist. Brick-making in Egypt, as in Assyria, was a royal monopoly. Generally sand was used for bedding, less frequently mud.

These brick walls in the larger buildings were often faced with stone in later periods, so that the risk of the sand being squeezed out was slight. Plaster or glazed tiles were also sometimes used for facing. The thickness of bed-joints was hardly ever more than two-fifths of an inch. Layers of alfa-grass, sometimes plaited, were often placed in the joints to give additional bond, or, according to one authority, to provide drainage. Where walls had to serve a defensive purpose, they were frequently reinforced with tree-trunks against the shocks of attack, so that a breach made in the lower part of a wall would not necessarily involve the collapse of the superstructure. This is found in works of very early date.

The first mastabas or royal tombs were made of sun-dried bricks, with battered sides, set back in stages, but stone was used for facing them as early as the first dynasty. The now rather shapeless pyramid at Hawara in the Fayyum has lost its stone casing, and we can see the sun-dried bricks of which its bulk is composed. Many other pyramids (but not the famous trio at Gizah) were similarly constructed.

The Egyptians built arches and vaults of brickwork

from very early times. The prevailing shortage of timber induced them to study economy of centering wherever possible. Fig. 3 shows the construction of a typical elliptical arch. The bricks used in arch-construction and vaulting were often very thin and flat, those at the Ramesseum measuring 14 in. by 7 in. by $2\frac{1}{3}$ in. It appears, from models that have been found, that the upper floors of Egyptian houses were often formed of an arched construction. Of the brick buildings erected in Egypt from six to one thousand years ago very little remains. The wonderfully dry climate has preserved many great structures of sun-dried brick, chiefly fortresses, that have long lost their facing, and others—such as the town walls of El-Kab, 37 ft. high and 30 ft. thick—that never were faced; but of the dwellings of the people, whether of *pisé* or of sun-baked brick, no remains can be expected in view of the ephemeral character of their materials. According to Capart, the introduction of burnt bricks cannot be dated earlier than the twenty-second dynasty, and their use was never common. The façades or exterior walls of the early structures were plain in appearance as befitted the nature of the material, but Prisse d'Avennes illustrates a brick building of late period which is decorated with niches.[1]

In the country that we now loosely call Mesopotamia, including Assyria, Babylonia, and Chaldea, though brick construction was practised nearly as early as in Egypt,

[1] On Egyptian brickwork, see Petrie, *Arts and Crafts in Ancient Egypt*, pp. 62–5; Choisy, *L'art de bâtir chez les Égyptiens*, pp. 11–151; and *Histoire de l'Architecture*, pp. 17–22; Bell, *Architecture of Ancient Egypt*, pp. 80, 132.

there were important local differences. The rich alluvial soil made excellent bricks, after admixture with chopped straw and exposure to the sun for two or three days. The size of these varied greatly, the thickness ranging from $2\frac{1}{4}$ in. to $4\frac{1}{2}$ in., and they were generally laid moist from the mould, instead of being completely baked in the sun first. This fact has been discovered from the impressions made by amulets placed between the brick courses. The impressions are found on the upper and not on the lower face, showing that the former must have been laid while still soft. The so-called 'drainage-channels' found in some of these old brick walls are now believed to be the marks left by bonding-timbers that have since decayed. Timber for fuel is nearly as scarce in Mesopotamia as in Egypt, and the introduction of burnt brick probably came from farther east or north-east, perhaps, as Choisy suggests, from Tibet; others, on the contrary, hold that it originated in Mesopotamia, and travelled thence via Persia and India to China. Such bricks were used in any parts of the building that were liable to disintegration by damp, i. e., the lower portions and the external facings. They were large flat bricks of regular sizes, marked with the name of the reigning king. The clay was reinforced with chopped reeds, kneaded by foot in shallow basins, moulded into bricks about 15 in. square and 4 to 10 in. thick, and burnt in an oven or kiln. Internal walls of important rooms in palaces, &c., were often faced with glazed bricks and enamelled tiles. Burnt bricks required mortar for bedding. A bituminous damp-proof mortar, obtained in Chaldea, was widely employed, sometimes reinforced with fibre; also another variety made of lime and ashes.

As in Egypt, no foundations were used, but large buildings were placed on a great podium or platform of earth in order that the latter might distribute their weight over as large an area as possible. Vaults of large flat bricks were constructed by the Assyrians in very early times. Fig. 4 illustrates one, and the same method was followed in the vaulting of so late a building as the great hall at Ctesiphon (*c.* A. D. 550) of the late Sassanian period, with a vault 86 ft. wide and 105 ft. high.[1]

In Persia brick was the normal building material, sun-dried for general purposes, burnt for vaulting and for positions requiring exceptional strength.[2] The burning was apparently effected by means of layers of dried grass between layers of clay. Burnt bricks were laid on a bed of good lime-mortar. For the great fortresses unburnt bricks were generally used. The manufacture of enamelled bricks, which became so characteristic of Persia in later times, continued.

The brickwork of the upper part of the Great Wall of China is partly burnt and partly unburnt, but is of comparatively late date.

In pre-Hellenic Greece, brick was largely used for house-building. Sun-dried bricks were employed, bedded in mud. Wooden beams were built into the walls, forming a sort of primitive half-timber framing. The palace at Tiryns (*c.* 1400–1200 B. C.) had walls of crude brick on a base of rubble masonry bedded in clay. In the Second Early Minoan period in Crete (*c.* 2600–2400 B. C.) large sun-dried bricks were used in wall-construc-

[1] On brickwork in Mesopotamia, see Choisy, *Histoire de l'Architecture*, pp. 86–91, 117–18; Layard, *Nineveh*, pp. 342–5.

[2] Choisy, *op. cit.*

tion in exactly the same way, and timber framing was employed to stiffen the walls. The surface of the brickwork was plastered. The floors of these houses were of flagstones, cobbles, cement, or beaten earth ; the ceilings of reeds daubed with plaster.[1]

The last material that one would associate with Hellenic architecture is brick, and no examples of brick buildings remain to us from that great period. Yet from the writings of Vitruvius and earlier authorities we know that brick was extensively used, not only in the dwelling-houses of the people (buildings of one storey only, resembling the pre-Hellenic houses just described), but also in important structures, including some of the monuments at Olympia. According to Vitruvius, sun-dried bricks were employed, about 1 ft. in length and 3 in. thick. It is thought that the walls of Athens facing Mount Hymettus constituted the principal brick structure in Ancient Greece.[2]

Brickwork was very largely used by the Romans. Careful translators of Vitruvius have concluded that up to his day, commonly believed to be the age of Augustus or thereabouts, only sun-dried brick was known, and that it was only through increasing contact with Asia as the Empire grew that the possibilities of hard burnt brick were realized. Every one has heard the famous boast of Augustus, that he found a Rome of clay and left it a city of marble. Choisy says that it would have been more truthful, if less dramatic, to have stated that

[1] Choisy, *Histoire de l'Architecture*, pp. 228, 245 ; Hawes, *Crete, the Forerunner of Greece*, pp. 29–30.

[2] Choisy, *op. cit.*, pp. 268–9 ; Anderson and Spiers, *Architecture of Greece and Rome*, p. 107.

he left it a city of brickwork filled in with concrete, adding that it was this new type of brick skeleton that made the greatest Roman buildings possible.[1]

Vitruvius affords to modern architectural students an excellent example of the all-round architect or 'general practitioner'. He writes with equal enthusiasm of the proportions of a cornice, the composition of brick-earth, and the construction of a water-organ. He is a great believer in tradition, quoting Greek precedent with obvious admiration whenever he gets a chance, but he is essentially 'modern' in his outlook, and criticizes new materials with discrimination. Writing of the various brick-earths, he says[2] that bricks should not be made of sandy or pebbly clay, or of fine gravel, partly because such things are heavy, partly because they are liable to be disintegrated by rain on the walls and 'the straw in them does not hold together on account of the roughness of the material'. They should be made of white or chalky or red clay, or even of coarse gravelly clays. These are smooth, durable, light, and easily handled. Bricks should be made in the spring or autumn to allow of uniform drying; if made in the summer they will dry too rapidly and so may crack. They should be made *at least two years before using*. He mentions one place where the local by-laws prohibit the use of bricks less than five years old. What better example could we offer than this to those wayward geniuses of this age who are for ever cursing the modern by-laws and sighing for the 'good old times'?

Vitruvius makes it even more clear that he knew nothing of burnt brickwork for general walling in a later

[1] Choisy, *op. cit.*, pp. 520–1.

[2] Vitruvius, II. iii.

passage,[1] where he quotes the city regulations in Rome as preventing the use of brick for walls, because the thickness of these is limited to $1\frac{1}{2}$ ft., and he says that in brickwork that would be sufficient to carry one storey only, therefore it becomes impossible to employ brickwork for the tenement buildings that are usually required in a large city. Now we all know from our beneficent 'Model By-laws' that an 18 in. wall of modern burnt bricks safely carries far more than one storey of superstructure, so we may infer that if burnt brickwork had been available for walling in Vitruvius's time it would not have been limited to the extent that he states. Outside the city boundary, where presumably tenement buildings would not be necessary, he recommends the use of unburnt bricks for general walling purposes, but with a coping of burnt bricks (to resist the weather).[2]

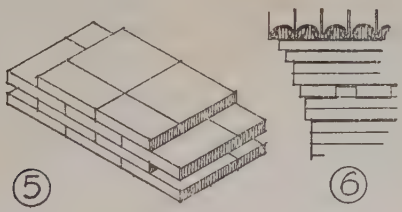
He is not very explicit on the question of bonding, but Fig. 5 shows the probable interpretation of the method that he describes for a '$1\frac{1}{2}$ brick wall', as we should call it. He gives full directions on sand, lime, and the mixing of mortar—all very sound and practical. A more detailed description of Roman construction in brick will be found in my fourth chapter, under the head of 'Concrete'. It was not exactly brick construction, but rather a combination of brick and concrete, that made possible the greatest achievements of the Romans in their wonderful Thermae.

It may, however, be remarked at this point that the Romans, as one would gather from the passages of Vitruvius quoted above, took great care both in the selection and the preparation of their brick-earth, as in

[1] Vitruvius, II. viii. 17. [2] *Ibid.*, II. viii. 18.

its subsequent burning. It is also known that they manufactured bricks extensively in Britain and in Germany. Besides ordinary bricks and roofing-tiles (see Chapter VIII), there are in English museums many examples of Roman flue-tiles, agricultural drain-pipes, and other clay products of great interest to modern students of building.[1]

The Roman tradition was closely followed in the succeeding centuries when inspiration came from East and West alike, those centuries whose architecture is generally known as 'Byzantine' in spite of provincial



variations. The most striking feature of Byzantine architecture is, of course, dome-construction. But in this chapter and the next it is necessary to omit any description of such monumental features as domes and vaults. These can be studied in any reputable text-book of historical architecture; but here I am only concerned with the humbler processes of building, the work that has a more human interest for us smaller fry of to-day just because it allows us the luxury of making comparisons with our own efforts.[2]

The Byzantines do not seem to have considered brick

[1] See fig. 205a. (iv).

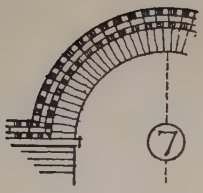
[2] On Byzantine brickwork, see Choisy, *op. cit.*, vol. ii; and his *L'art de bâtir chez les Byzantins*, passim.

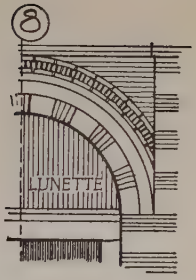
a base material. They appear to have intended it to show on the exteriors of their churches, which were at first quite plainly treated without any attempt at plastering, as indeed at St. Sophia itself originally. In this they followed on the same lines as in the early Christian basilicas of Rome. St. Sophia is essentially a brick building, not only as regards its great walls but also the huge semi-domes over the apses and the enormous flat dome itself, which, according to Sir Thomas Jackson,[1] is formed of brick ribs, each 2 ft. 4½ in. wide at the spring. The bricks used are about 13 in. by 6½ in. by 2 in. The flat domes of St. Mark's at Venice (concealed by the later bulbous lead-covered domes) are also of brick. But of Byzantine walling, as of Roman, I prefer to say more in my fourth chapter, because it is really a form of rubble concrete walling, only faced with brick or stone.

The most interesting feature in connexion with Byzantine brickwork at this stage is the process by which, for the first time, it came to be ornamentally treated. The great flat wall-surfaces were panelled into shallow arcading. Round the arches were bands of bricks set diamond-wise on plan (Fig. 7); or they were arranged to form trellises or guilloches. Then, by using brickwork and stone to form alternate courses and voussoirs, further variety was obtained (as I shall explain more fully in Chapter IV), and Fig. 8 shows details from a Serbian church of much later date but of purely Byzantine character, where this use of ornamental brickwork is highly developed.

Brick arcading was freely used at Ravenna, and one

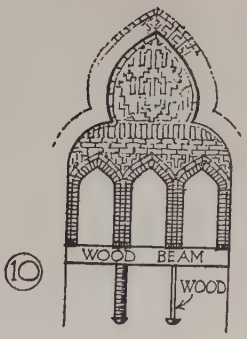
[1] Jackson, *Byzantine and Romanesque Architecture*, vol. i, pp. 96–7.

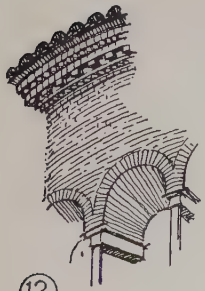

7

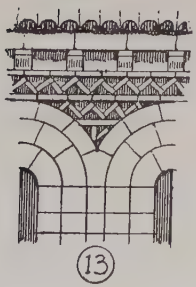

8
LUNETTE

9

11


10
WOOD BEAM
WOOD


12


13

great authority [1] attributes the familiar Lombard arcading of later centuries to a Ravennate origin. The plain exteriors of the Byzantine churches at Ravenna also have brick cornices, such as that illustrated in Fig. 11, which is from the tomb of Galla Placidia there.

We must now turn eastwards to see something of Saracenic brickwork in Cairo, which may be taken as typical of other Muslim cities for our purpose, as all the crafts were highly developed there. Prior to the ninth century the early mosques had been built of colonnades of antique marble columns, rifled from pagan temples and Christian churches, with which Egypt was liberally supplied. No doubt plain brick enclosing walls would be used externally. But the remarkable mosque of Ibn Tulun, erected in Cairo in the ninth century, was built of burnt brick piers and pointed arches, so much of a novelty that the origin of the pointed arch, properly constructed and used, is now universally attributed to this one building. Something similar had, however, been done in the great mosque outside the walled city of Samarra (so well known to numbers of British soldiers during the War) in Mesopotamia. The latter mosque was built a few years earlier than that of Ibn Tulun, and as Ibn Tulun himself was educated at Samarra there is probably an explanation here of the sudden innovations at Cairo. At Ibn Tulun's mosque the piers are 8 ft. by 4 ft., with engaged shafts worked in brick on their angles and bonded into the main piers. The arches between have a span of about 15 ft. There were none of the ugly tie-beams across the spring of the arches that are so usual a feature in Saracenic buildings,

[1] Rivoira, *Lombard Architecture*.

but the tops of the massive piers are tied with wooden plates dovetailed together. The mortar joints are wide and irregular, but, as all the brick surfaces were covered with stucco, this did not detract from the appearance. Our so-called 'English Bond' is used throughout. The foundations of the piers were carried down to natural rock. The exterior of the building, with its cusped niches and curious battlements, is also very suggestive of Mesopotamian work.[1] One curious result of this sudden craze for brick-construction is to be seen in another small building of the same reign in Cairo, where stone voussoirs were made in obvious imitation of brick-work (Fig. 9).

During the best periods of Saracenic art in Cairo, from the eleventh to the sixteenth century, brickwork was not very much used for mosques, but was the staple material for the smaller dwelling-houses. Then from the sixteenth or seventeenth century up to comparatively modern times there was a remarkable vogue for brick-building in the old towns of the 'Delta': Damietta, Rosetta, and others with less familiar names. No stone was procurable in this part of Egypt, so brick came to be ornamentally used with great effect for the embellishment of façades. Bricks were arranged in patterns, and blue or black bricks were introduced as diaper-work, just as was done in contemporary buildings in East Anglia. Mortar was sometimes used, sometimes not. But the joints were always pointed a brilliant white to show them up and to give a heightened effect to the colour and arrangement of the bricks. All sorts

[1] This mosque is fully described and illustrated in Chapter III of my recent book *Muhammadan Architecture in Egypt and Palestine*.

of bond were used, and terra-cotta and faience plaques were also employed to give additional variety. But the strangest feature of Saracenic brickwork is the use of so-called 'candles' or pendants (Fig. 10), as unconstructional as the pendants of a stone Gothic fan-vault, for they hang down from a wooden beam without any visible means of support, this being provided by a rod that runs down their centres.[1]

During the Romanesque period the chief centre of brick-building was Northern and Central Italy. Nowhere does it appear to greater advantage than in the square *campanili* of such churches in Rome as SS. Giovanni e Paolo and S. Francesca Romana. These were divided into stages by simple dentil cornices of brick. At the remarkable church of S. Pietro, Toscanella (A. D. 712–43), bricks are employed in an unusual fashion, placed on edge in the spandrels of the arcading, with deep spaces between to give a shadow (Figs. 12 and 13 illustrate Romanesque brickwork details from Italy). In S. Ambrogio at Milan brickwork is largely used in the vaulting-ribs, arches, and other important structural features. St. Alban's Cathedral may be regarded as an English example of Romanesque brickwork, but that is not strictly accurate. The bricks used there were taken from the old Roman city of Verulamium.

Though Gothic brickwork is not by any means unknown in England, it is exceedingly rare before the fifteenth century; but in other parts of Europe, especially in North Italy, North Germany, parts of Spain, Belgium, Holland, and South-west France, it was

[1] 'Delta brickwork' is fully described in my book on *Muhammadan Architecture* cited above.

the chief building material throughout the Middle Ages. In Northern Italy, as we have seen, it was the traditional and natural material to use, and the beginning made by Lombards and Byzantines towards treating it decoratively was continued during the subsequent centuries. Street's book, *Brick and Marble Architecture in North Italy*, had a great vogue when it was first published in 1855, with its numerous illustrations of detail; but it did a great deal to spread the use of misapplied 'ornamental' brickwork all over this country. Somehow these shafts and crestings and arcades, carried out in pressed brick with black cement joints and sprayed over mid-Victorian villas and churches and chapels, have no charm at all for those who have seen them in their native home in Italy. They furnish an excellent warning against thoughtless copyism, for England itself abounds with good traditional brickwork, and there was no need to turn to Italy if copyism had to be resorted to. Moreover, the copyism was inaccurate. The Italians did not use either bricks or mortar of the hideous colours adopted by their Victorian imitators.

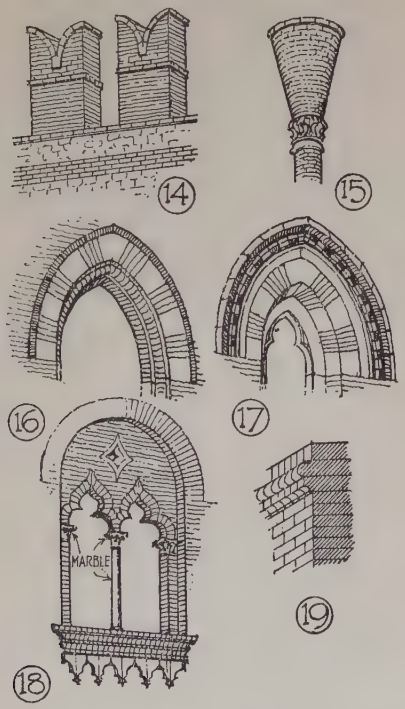
But there was nothing remarkable about the colour or quality of medieval bricks in Italy. They were almost always red, generally a little larger than ours, with rather wide mortar joints. The dressings were usually in a finer quality of brick. One strange practice consisted in chiselling the faces all over with diagonal lines, in alternate directions on each adjacent pair of bricks. The reason for doing this is not very evident, but was possibly to give a contrast between adjoining bricks. The size of bricks used varied very much—from $9\frac{1}{2}$ in. to $12\frac{1}{2}$ in. in length, 5 in. in breadth, and $2\frac{1}{4}$ in.

to $3\frac{1}{4}$ in. in thickness being common dimensions—while an early example from Venice has bricks as small as 7 in. by 2 in. But moulded bricks (Fig. 19) and moulded blocks of terra-cotta were made in every imaginable size and shape. Pointed arches often had voussoirs of brick and stone alternately, surrounded by one course of dark red bricks as a frame (Fig. 16); or sometimes the surrounding line was more complex, consisting of brick Venetian dentils, or of a hood-moulding such as we call a 'drip-mould' (Fig. 17). Another common form was a brick 'dog-tooth'. The plate-tracery of the enclosed lights was sometimes wholly in brickwork, even when cusping was included (Fig. 18), though it was more usual to make the points of the cusps of stone. Brick battlements of two main types are found, the quaint forked or swallow-tailed Ghibelline variety characteristic of Verona (Fig. 14), and the more flamboyant Venetian type, both assuredly derived from the Saracens, and by them from earlier Sassanian buildings. Another curious brick feature occasionally seen still in Venice is the funnel-like chimney of the older palaces (Fig. 15), not at all a thing of beauty. Among important brick churches in Italy are S. Petronio at Bologna and the Frari at Venice.

In North Germany, from Hamburg to Lubeck, are found great churches constructed almost entirely of brick, even their tracery and crockets. Albi Cathedral in the south-west of France is another noteworthy example, and there are many others at Toulouse and in the 'brick districts' of Europe already mentioned.

Brickwork was extensively used in Italy and elsewhere from the beginning of the Renaissance movement;

and in many buildings, such as the dome of the cathedral at Florence, it was employed constructionally in a novel way. But that famous design, like that of our own



St. Paul's, is a feat of monumental architecture that falls outside the scope of this little book.

The re-introduction of brickwork into England was probably due to Flemish weavers, who settled in East Anglia and a corner of East Kent in large numbers from the fourteenth century onwards. It was chiefly used for

building in Flanders because stone was scarce there, and, as it happened, the same applied to East Anglia. At first the bricks were imported, and, for that reason perhaps, they were so expensive as to make the progress of brick architecture somewhat slow. From 1450 onwards there are many brick buildings to be found, and from 1500 they are really numerous all over eastern England. Contemporary documents record the price of bricks in London in 1479 as 4*s.* 7*d.* per thousand, and at Stonor in 1416–17 as 4*s.* per thousand. A London entry of 1568 gives 3*s.* per thousand.

The word 'brick' has a French origin, and does not appear in England before the fifteenth century. An entry in the building-accounts of Lincoln's Inn in 1517–18 refers to 'Les Brikes'. The new bricks measured generally $9\frac{1}{4}$ in. by $4\frac{1}{2}$ in. and from $1\frac{1}{2}$ in. to $2\frac{1}{2}$ in. thick, but usually 2 in. to $2\frac{1}{2}$ in. At Tattershall Castle (*c.* 1450) they are only 8 in. by 2 in. The length of $9\frac{1}{4}$ in. at this period may be one-quarter of the Flemish ell of 37 in., which was a standard long measure in England up to 1553. But these bricks were of a very different type from the flat Roman 'tiles' that had been occasionally used, almost in the Roman way, at Colchester and elsewhere during the Middle Ages. One would expect that another feature introduced from Flanders would have been our 'Flemish Bond'; but, like so many terms used in the modern building trade, this name appears to have no foundation in fact, and Flemish bond is rare in Flanders. (Both Flemish and English bond were used by Inigo Jones early in the seventeenth century.) East Anglian brickwork has, however, some features that are probably due to the Flemings, especially the stepped

gables or 'corbie-steps' seldom found elsewhere in England. During the seventeenth century these gave place to gables of curved outline, again introduced from overseas; and in the reign of William and Mary, when everything Dutch was in the fashion, the low pediments and heavy cornices imported by Wren and his followers from Holland drove all gables out of the field. There is an old house at Rye, one of the English towns most favourably placed for receiving foreign influences, where 'Dutch clinkers', the small hard yellow bricks now chiefly used for stable paving, are found. One of the earliest examples of brickwork in England is the north and east part of Queen's College, Cambridge (1448). Here the bricks are burnt hard to a dark purple red (as in the older part of Hampton Court), are irregular in shape, have wide joints, and run four courses to 11½ in. They measure 8 in. by from 1¾ in. to 2 in. by 4 in. to 4¼ in. More commonly early bricks run about five courses to a foot. Wolsey's buildings at Hampton Court (1515–20) form perhaps the best example near London for the study of early brickwork. It is recorded that the large house at Kirby Muxloe in Leicestershire was built by a gang of Welshmen working under English foremen, and that at least some of the bricks were imported from Flanders. The consignments ranged from 13,000 to 24,000 per week, and the total number of bricks used was 1,342,500.[1]

The two chief brickwork schools in rural England

[1] On early English brickwork in general, see Blomfield, *Short History of Renaissance Architecture*, pp. 262–3; Floyer, 'English Brick Buildings, Henry VII and VIII' (in the *Builder*, 27 July 1923); Innocent, *Development of English Building Construction*, pp. 149–52.

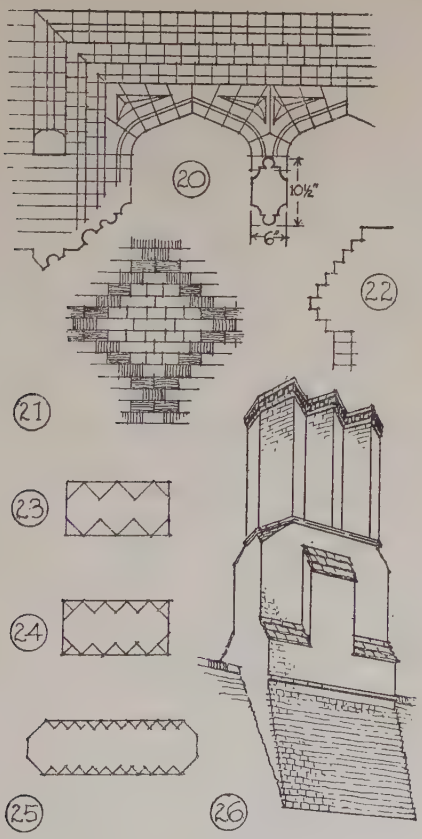
prior to the eighteenth century—when local tradition in craftsmanship was largely swamped by the copy-book spirit of the Palladians—were those of East Anglia and of Surrey, Sussex, and Kent. To what has been said of the former a little more may now be added. A characteristic of East Anglian work is the use of diaper patterns, generally of blue or black bricks on a ground of ordinary red bricks (Fig. 21). Brickwork was employed in the construction of transomes, sills, and heads, as well as for jambs and mullions (Fig. 20). A brick transome naturally presents some difficulties. At first no extraneous means was employed to supplement the tenacity of the mortar-joints, but in late Tudor examples an iron bar was run through the bricks of the transome, or under them (like a modern ' chimney-bar ' over a fireplace). Instances of these transomes may be seen at Layer Marney Towers and at Eastbury Manor House near Barking, both in Essex.

Chimneys were sometimes of very elaborate form, but most often consisted of a series of faces at 45 deg. to the main face of the shaft, as illustrated in Figs. 23–6. The slopes of the set-offs of stacks were sometimes tiled (Fig. 26), sometimes special splayed bricks were used, and occasionally plain set-offs (Fig. 22), which cannot be recommended. Terra-cotta was frequently employed in conjunction with brickwork in East Anglia during the first part of the sixteenth century.[1]

In Surrey, Sussex, and Kent the character of the brickwork in general is less elaborate and more rustic than in East Anglia where Flemish influence was so

[1] On East Anglian brickwork, see B. Oliver, *Old Houses in East Anglia.*

strong. We do find occasional twisted chimneys, corbie-steps, and curved gables (Figs. 27–30), but these features

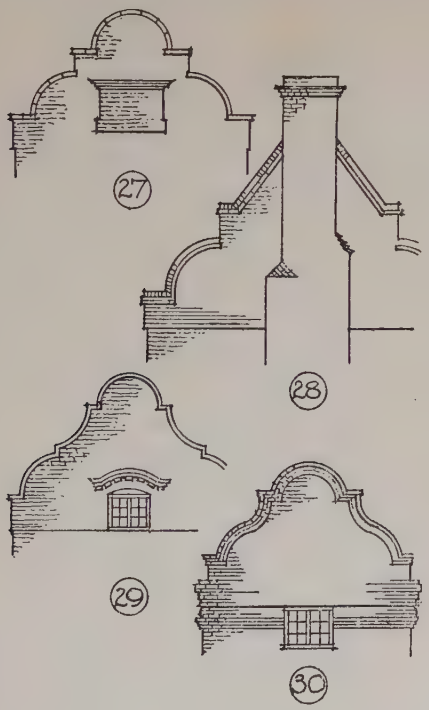


are mainly confined to towns, especially to the towns of East Kent where foreigners were most often found. The old bricks were generally fairly large and thin (10 in. by

5 in. by 2 to $2\frac{1}{4}$ in. being a common size), hard, rough, uneven in shape and size, and built with wide joints. Somewhat porous at first, they improved on exposure to the weather.

Undoubtedly the chief attraction of this school of brickwork lies in the prominence of the chimney-stack in design, and the wonderfully simple means by which variety in its treatment was obtained. The early fireplace had an enormous opening, usually from 3 ft. 6 in. to 5 ft. deep, and of any width up to 14 ft. or so. The object of this was to collect smoke from a wood fire. (Modern students of the past should remember that such a fireplace is just as unsuitable as it can be for a coal fire.) Thus the chimney had a bold projection externally which greatly improved its appearance. Brickwork was erected without any regard for economy up to the shafts of the chimneys, but these were often only half a brick thick, as were the 'feathers' or brick walls between the flues. The flues were larger than we make them nowadays, and never less than 14 in. by 9 in. The plans of the stacks (Figs. 35–40) are very interesting, and consist of variations of simple elements, as the illustrations show. Sometimes the different flues form separate shafts with a small space between, sometimes they are connected. The lower part of the stack on elevation is designed with great ingenuity, being set back in carefully graduated stages, usually without any attempt at symmetry until the size of the stack itself is reached. But the most striking fertility of invention is shown in the design of the chimney-caps (Figs. 31–7), which in these counties are seldom moulded, but are simply treated with the plainest possible oversailing courses of

ordinary brickwork. I know of nothing in our architecture so simple, so natural, so English, and so completely successful as these beautiful chimneys of southern England. This is the tradition that should inspire us



when we are designing cottages, shops, factories, or other 'utilitarian' buildings. Here are the plainest materials perfectly handled, without any straining after effect or anxious referring to copybooks, and the result is as admirable as one can find in any cathedral or palace.

Very often the chimney-stack was of brick, the remainder of the building being of timber-framing, filled in with brick in patterns, or plastered, or covered with weather-boarding.[1] In the 'black and white' districts of the Midlands, from Worcestershire to Lancashire, chimney-stacks were of brick. In general design they followed either the East Anglian or the south-eastern school.[2]

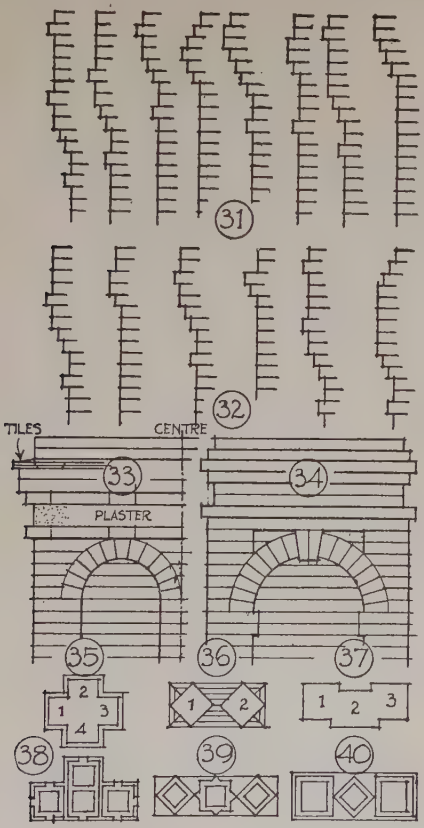
A curiously similar story can be told of early brickwork in America, where it is stated that the first brick building was erected on Manhattan Island in 1633 by the Governor of the Dutch West India Company. The first bricks were imported from Holland, at this date a great centre of the brick-making industry, and for some time they continued to be shipped from Holland and England. In America the first bricks were made at New Haven in 1650, but the manufacture spread slowly through New England and the quality of the early bricks was inferior. It must be remembered that houses were largely built of timber during the 'Colonial' period in America, where they were less crowded together than in the English towns.

The Great Fire of London was only one of several factors influencing the development of brickwork in the second half of the seventeenth century in England. Others were the strong Dutch influence at the Court of William and Mary (leading to the design of houses almost identical with those erected in Holland at the

[1] On old brickwork in Surrey, see Curtis Green, *Old Cottages in Surrey*; and for Kent and Sussex, see E. G. Dawber, *Old Cottages in Kent and Sussex*.

[2] E. A. Ould, *Old Cottages in Shropshire, Herefordshire, and Cheshire*.

same time), the denudation of the English forests to provide for the expansion of the fleet under Pepys and



his colleagues, and the appearance of the professional architect. The Fire of London led to the substitution of brick for what we now call ' half-timber ' houses in the City of London, and also to the passing of several

Acts of Parliament forming the basis of the modern London Building Act.

These are summarized in Batty Langley's *A Sure Guide for Builders*, published in 1729, and are worth paraphrasing for comparison with modern legislation. No. 1 deals with foundations, and is of Charles II's reign. When the trenches were dug, ready for the footings, the builder had to notify the City Surveyor, who then inspected them. A fee of 6*s*. 8*d*. was payable for this service. No. 2 deals with party walls, and is naturally of considerable length. In general arrangement it resembles the present law, but the thickness of such walls is laid down as 14 in., except in the attics, where they may be 9 in. Under Queen Anne, these figures became 18 and 14 in. respectively, and it was ruled that the party wall must be carried up 18 in. above the level of the roof. No timber was to be let into any part of the party wall. The amount to be paid by the two owners was defined, and the method of measuring and pricing the brickwork clearly laid down. Batty Langley interpolates the following amusing note on the clause explaining how 'toothing' was to be left for future walls:

'But 'tis to be observed, that if the first House be built any considerable Time before the second, and is wholly settled in its Courses, I can't see how the other Buildings, afterwards built into the Toothings of the First, can be incorporated and firm; for since that every Building of Brick doth settle very much as the Work becomes dry, the settling of the last Buildings must cause a Fracture at the Toothings of the first, which being then settled, resists the Settlement of the last, and therefore cannot be firm and sound. Hence 'tis much the best Way to build all together, if Time and Conveniency permits.'

No. 3 prescribes the thicknesses of ' Front and Rear Walls ' as follows :

Houses of ' first rate of building ', Cellars 18 in., Next 2 floors 14 in., Garrets 9 in.
Houses of ' second rate of building ', Cellars 22½ in., Next 2 floors 18 in., Third floor 14 in., Garrets 9 in.
Houses of ' third rate of building ', Cellars 27 in., First floor 22½ in., Next three floors 14 in., Garrets 9 in.
' Houses of the fourth rate of building, being chiefly for Noblemen, &c., have their Thickness left to the Discretion of the Architect.'

(There is an undemocratic flavour about the last clause that would horrify a modern councillor of the L.C.C.)

In Queen Anne's reign another Act prescribed the construction of chimneys, and here again we see the germ of our modern rules. The jambs and backs are to be 9 in. thick, the chimney walls 4½ in. All ' flews ' are to be parged, all hearths except on the ground are to be supported on trimmer-arches, arches are to be built over all fireplaces, and no woodwork is to be fixed nearer than 4½ in. to any fireplace or ' flew '.

Still further regulations control not only the height of rooms, according to the ' rate ' of building, but also the scantlings of timber. Here again we are reminded of the ' good old times ' in the last clause, which runs :

' The fourth Rate of Buildings, being such as are appointed for Persons of extraordinary Quality, situate in magnificent Squares, &c., may have the Heights of their Stories and Scantlings of their Timbers at Pleasure ; but they must not exceed four Stories in Height, exclusive of the Cellars and Garrets.'

An Act of George I (1726) lays down rules for the brick and tile makers at the request of their Company,

which had been incorporated originally by Queen Elizabeth. The burning of sea-coal ashes ('Spanish') and the use of 'breeze' was prohibited, the time for clay-digging was fixed between 1 November and 1 February, and the dimensions of a brick, which had already been standardized in 1477, 1567–8, and 1625, were regulated once more. Langley disagrees with every single one of the new clauses, showing that even in his day the architect was a conservative at heart, but he does at least give very practical reasons for his objections.

For further light on the craft of the bricklayer rather more than two hundred years ago, we may turn to that versatile writer Joseph Moxon, F.R.S., whom we have already met in our first chapter. He devotes fifty pages of his manual of building-construction [1] to brickwork, discussing successively materials, tools, and workmanship. Speaking of brick-earths, he says that

'The whiteish Chalky sort of Earth and the Redish are the best. . . . But here in England they [bricks] are made for the most part of a yellowish coloured fat Earth somewhat Redish. . . . In Holland they make small ones being about six Inches long, three Inches broad, and one Inch in thickness. Which sort of Bricks is commonly used here in *England*, to pave Yards or Stables withal; and they make a good Pavement, and are very Durable, and being laid edge-ways looks handsomly, especially if laid Herring-bone fashion.'

After giving the size of common bricks as 9 in. by $4\frac{1}{4}$ in. by $2\frac{1}{2}$ in. or sometimes 3 in., he proceeds that the best brick-earth comes from Kent, where also the best rubber bricks are made. (These red rubber bricks were among

[1] Moxon, *Mechanick Exercises, or the Doctrine of Handy-works* (1678).

the novelties introduced into England from Holland.) He says that these are commonly used for dressings in conjunction with grey Kentish bricks for walling, and adds of the latter, ' as Pliny says, (speaking of Bricks,) that they will last to Eternity ' (an altogether unnecessary occasion for including a reference to the classics).

He describes another make of bricks used for paving ' of a stronger sort of earth ', which cost about 6*s.* a thousand more than 'Ordinary Bricks'. Also that paving tiles are made in several counties, especially Surrey, of the following sizes, 12 by 12 by 1¼ in., 10 by 10 by 1¼ in., and 8 by 8 by 1 in., and that these are polished or rubbed with sharp sand, and laid with a close joint.

He says that there are two sorts of lime, stone lime (the strongest) and chalk lime, both of which are burnt in a kiln. The former is used for external plastering and the latter internally :

' and that which is made of greasy clammy Stone, is stronger than that made of lean poor Stone ; and that which is made of spongy Stone, is lighter than that made of firm and close Stone ; that is again more Commodious for plastering, that for Building.'

' And the Fire in *Lime* burnt, Asswages not, but lies hid, so that it appears to be cold, but Water excites it again, whereby it Slacks and crumbles into fine Powder.'

After noting the caustic properties of lime, he quotes Vitruvius on the mixing of mortar, but says that the proportion of sand seems too high, adding that ' Here at *London*, where for the most part our *Lime* is made of *Chalk* ', about 1½ parts of sand by measure are used to 1 of lime. He recommends that mortar should be

allowed to gain strength by standing before use for as long as two or three years, 'if it lye in an heap', and sand for brick mortar should be as sharp as possible.

'"Cements" of a sort are used by some bricklayers, in Cementing of Bricks for some kind of Mouldings, or in Cementing a Block of Bricks, as they call it, for the Carving of Scroles or Capitals or such like, &c.,'

called cold and hot cements; the former, he says, is known to few bricklayers, whereas the second is common. His recipe for the former is amusing:

'Take ½ a Pound of Old Cheshire-Cheese, pair of the Rine, and throw it away, cut or grate the Cheese very small, and put it into a Pot, put to it about a Pint of Cows-milk, let it stand all Night, the next Morning get the Whites of 12 or 14 Eggs, then take ½ a Pound of the best Unslackt or Quick Lime that you can get, and beat it to Powder in a Morter, then sift it through a fine Hair Sieve into a Tray or Bole of Wood, or into an Earthen Dish, to which put the Cheese and Milk, and stir them well together with a Trowel, or such like thing breaking the Knots of Cheese, if there be any, then add the Whites of the Eggs, and Temper all well together, and so use it; this Cement will be a White Colour, but if you would have it of the Colour of the Brick, put into it either some very fine Brick-Dust, or Almegram, not too much, but only just to colour it.'

The 'hot' cement involves a less appetizing recipe, and has to be boiled in 'a Pipkin or other Vessel'.

The twenty-three tools named by Moxon as forming the bricklayer's outfit and illustrated on one of his plates, resemble those in use to-day so nearly that it is superfluous to give their descriptions here. Among other items of plant mentioned is 'a *Skreen* made of Boards and Wyer'.

His section on Workmanship begins, as it should do, with foundations. Before the footings are laid,

'the Master-Bricklayer, or else his Foreman, (which ought to be an ingenious Workman,) must in the first place try all the Foundations, in several places, with an iron Croe, and Rammer, or, indeed with a Borer (such as Well-diggers use, to try what Ground they have to produce Water) to see whether the *Foundations* are all sound, and fit to bear the weight which is to be set upon them.'

If not, he must dig down till firm ground is reached, or else adopt one of the following alternatives: (*a*) Ram in a course of large stones, spreading a foot on each side of the wall (though in any case the footings will spread 4 in. on each side of the wall). (*b*) For still looser soil, first lay pieces of oak across the trench, about 1 ft. apart, and then planking of the width of the wall above them, well spiked to the oak pieces. (*c*) For very loose soil, use 'good Piles made of Heart of Oak', long enough to reach firm ground, with a diameter about an eleventh of their length, 'driven down with a Commander or an Engin for that purpose', and with planks spiked to the piles, which should be set as close as possible. (*d*) For soil which is only loose in parts, with firm patches, he recommends the use of inverted arches, giving details of these on his Plate 3. After discussing one way of doing this, he says: 'The Ingenious Surveyor Mr. *Hook*, made use of this Artifice, as I am informed, in building the Lord *Montague's* brave House in *Bloomsbury*, in the *County* of *Middlesex*.'

After briefly noting the difficulty of 'setting-out' foundations from small-scale plans, he proceeds to give the following maxims for good brickwork in walling:

Mortar to be mixed 1 to 1½ if the sand is sharp, otherwise more sand is to be used! (*b*) Slake lime gently in small quantities. (*c*) Beat all mortar 3 or 4 times before use to break up lumps and to 'incorporate the Sand and Lime well together'. For good work let the mortar lie one or two days before final beating, and use. (*d*) Dip each brick *separately* in water before laying, if the weather is hot.

'The reason why I mention a small piece of Work is, because 'tis a great deal of trouble to wet them for much Work, or a whole Building, and besides it makes the Workmen's Fingers sore; to prevent which they may throw Pales of Water on the Wall after the bricks are lay'd as was done at the building of *Physicians College* in Warwick-Lane, by order of the Surveyor, which was the aforesaid Ingenious Mr. *Hook*, if I mistake not.'

(*e*) Cover all walls in summer to prevent too rapid drying. (*f*) Cover all walls in winter to prevent rain, snow, or frost harming the new brickwork. (*g*) Do not let any one wall of a building rise more than three feet higher than the adjoining walls, otherwise one is liable to 'Cracks and Setlings in the Walls'. (*h*) Avoid straight joints both outside and inside the walls by providing a proper bond. (He discusses bonding problems in detail, including the use of 'Closures', 'Bats', 'Stretchers', 'Headers', 'Quines', and 'Toothings', and gives plans of bonding where alternate courses are shown in black and dotted lines, like a modern textbook. All his diagrams show 'English' bond, not Flemish.) (*i*) 'In Summer time use your Morter as soft as you can, but in the Winter time pretty stiff or hard.' (*j*) If in London, you must make your walls of such thickness as the Acts of Parliament direct, elsewhere

you may use your own discretion. (*k*) Lay the ends of all girders, lintels, ' Torsels for Mantle-Trees to lye upon', and all other structural timbers, on loam and not on mortar, as mortar corrodes timber.

He concludes his chapter on brickwork with instructions as to the use and reading of scale plans and elevations, the preparation of templates of ' Wainscot or Pastboard ' for mouldings in brick, and the drawing and setting-out of elliptical and straight arches.

Moxon's book is contemporary with the age of Wren, when simple brick architecture in this country reached its climax. Country houses such as Groombridge Place, the Inns of Court, most of our cathedral closes, the streets of old market towns, and some of the quarters of London that were fashionable suburbs in Wren's day, all display the attraction of good material handled without affectation but without a mistake. This charm is not in the least due to profuse ornament (on the contrary these buildings are all severely plain), but to good craftsmanship and good proportion. Wren's brickwork probably appears at its best in his buildings at Hampton Court and in the Orangery in Kensington Gardens, now for many years subjects of study among architectural students.

But after his day the direction of craftsmanship came more and more into the hands of the professional architect, and the individuality of the bricklayer, as of all other craftsmen, tended to be submerged. An age so concerned with formalism as was the later eighteenth century could not be so favourable to the crafts, and it was not until late in the nineteenth century that brick was recognized again as one of the great building materials.

III

MASONRY

In dealing with masonry it is difficult to draw any distinction between construction and architecture. Whether in Greece of Hellenic times or in England of the Middle Ages, architecture and building in stone were synonymous. It is therefore impossible to deal at all adequately with masonry in one short chapter. To make the subject even manageable, we must exclude all masonry on the grand scale and in its more complex forms, limiting ourselves to the study of its minor aspects and its practical side. It is not my business here to look for ' Sermons in Stones '.

The oldest masonry of which we have any accurate knowledge is that of the ancient Egyptians, who used limestone, sandstone, granite, basalt, alabaster, and diorite. The limestone cliffs forming the desert escarpment on each side of the Nile valley have always supplied excellent stone, the finest variety being obtained from the Muqattam Hills, near Cairo. These cliffs extend 400 miles southwards from Cairo. Soft sandstone from Silsilah was commonly used from the twelfth dynasty onwards, especially in the Thebaïd. Red granite came from Aswan, where the quarries still remain, with evidences of the methods used for obtaining the stone. The use of the red quartzite sandstone from the Jabal Ahmar (' Red Hill ') near Cairo became common from the twelfth dynasty.

Professor Petrie and others [1] have described the system of quarrying stone of various kinds. Limestone was obtained by means of galleries, from the sides of which great blocks were cut, but the largest of all had to have a trench cut round them. The same method was used for sandstones. Fissures and cracks were so carefully avoided that a wall of stone containing them was left in position, often extending from top to bottom of the quarry. Granite, originally obtained in the form of water-worn blocks from the First Cataract, was afterwards quarried. It is generally believed that it was split from its bed by means of rows of wooden wedges that were wetted and allowed to swell after being fixed in position.[2]

Blocks of masonry had their edges dressed first; next the surfaces were tested with a string stretched across two offset sticks resting on the edges, and then the diagonals were tested in the same way. The final smoothing was tested with a plane smeared with red

[1] On Egyptian stone-quarrying and masonry, see Petrie, *Arts and Crafts in Ancient Egypt*, pp. 69–76, 142; Choisy, *L'art de bâtir chez les Égyptiens*, pp. 53–93; Simpson, *History of Architectural Development*, vol. i, p. 25.

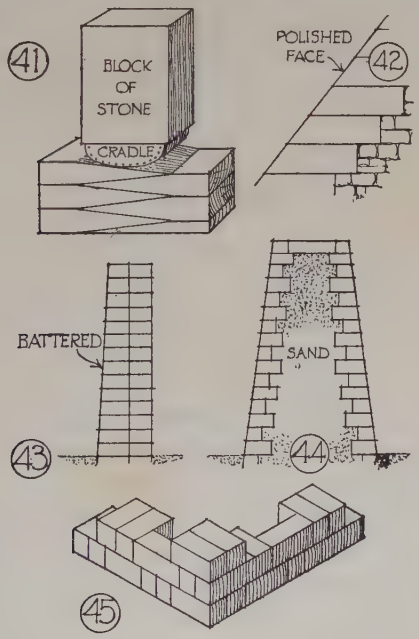
[2] In a recent article, Mr. R. Engelbach states that discoveries at Aswan in 1922 proved that the enormous obelisk lying in the quarries there was quarried as follows. 'The top layers of rock were removed by pouring water on the granite after it had been strongly heated by papyrus fires. This heating and cooling method is used in the Indian granite quarries at the present day. Having reached a level where the granite appeared to be free from flaws for the desired length, the surface was rendered flat by dressing with large balls of dolerite—a rock akin to diorite—which occur in some desert valleys in Egypt. These balls weigh from 9 to 15 pounds. A surprising result of the study of the Assuan obelisk is that neither chisels nor wedges were used in detaching it from the quarry; the dolerite balls were the only tools employed.'

ochre, which left a mark on any projecting irregularity. Granite and other hard stones were sawn or cut with tubular drills. Sand was used for cutting the softer stones, and emery for the hard rocks, the small pieces of emery being fixed in a saw-blade.

Professor Petrie also describes the methods for raising the enormous stone blocks to their position in the building. Instead of scaffolding, inclined ways of earth or brickwork were constructed to the top of all walls, perhaps revetted with masonry. This apparently cumbrous method is, however, easily explained when one remembers that timber in Egypt is scarce, whereas labour was, as we have seen in Chapter I, scandalously cheap. Moreover, even if the design of framed timber scaffolding had been understood in those days, it is unlikely that it would have sufficed for the enormous blocks of stone used. Those in the base of the Great Pyramid at Gizah weigh 16 tons. Small blocks were 'rocked' on wooden cradles, a wedge being inserted every time that the block was rocked to and fro with the aid of crowbars (Fig. 41). Obelisks, which are known from remaining examples to have weighed over 500 tons, and according to Egyptian and Roman records must have weighed 1,000 tons, were floated down the Nile from Aswan on barges, then rolled and dragged up to the top of an incline (which in one case was $\frac{1}{4}$ mile long, 95 ft. wide, and 103 ft. high on the slope, revetted with timber and brushwood), and at the top of the slope were gradually tipped over the end on to the base prepared for them, a cavity filled with sand being used to take part of the weight during the tipping process.

Mortar of lime and sand, as we understand it, was not

used, a mixture of lime and plaster-of-paris being employed as a rule. In the Great Pyramid the vertical masonry joints were only one-fiftieth of an inch thick, and it is difficult to see how they were filled with plaster,



as they certainly were. The core of the Pyramids at Gizah, of rubble masonry (Fig. 42), was grouted with coarse plaster. This plaster was obtained from the limestone quarries, but, owing to scarcity of fuel, it was often badly burnt and therefore lumpy. Metal and sycamore dowels were used to secure blocks in position. One such has been found in an obelisk at Luxor. Dove-

tail-shaped dowels were used for connecting the drums of columns, which were seldom monolithic. The great temple walls were built in two thicknesses, with a through vertical joint and no bond-stones (Fig. 43). For the pylons a similar method was used (Fig. 44), but the space between the two battering walls was filled up with sand. The Egyptians were limited only by the size of the lintels and ceiling-slabs that they could quarry and handle. Enormous and massive as was the effect produced by their system of trabeated construction in stone, it was often daring in the risks that were taken, and the strength of material was strained to the very limit of safety.

In Assyria in early times masonry construction was less important, and was chiefly confined to facing. Fig. 45 shows the method of bonding the facing-blocks into the wall. In Persian buildings the blocks were held together by dovetailed cramps, probably of metal, and the use of stone was mainly restricted to colonnades, plinths, and dressings.[1]

In pre-Hellenic Greece and in Crete masonry was largely employed. In Crete small rough stones were used at first, set in a mass of clay, then the size of blocks was increased and the thickness of beds decreased. The so-called 'Cyclopean' masonry was relatively late in date. The best masonry is of the Middle Minoan period (say 2200–1700 B. C.). Finely squared and closely fitting blocks were then used, some as large as 6 ft. 6 in. by 5 ft. Mycenean or Pelasgic masonry, commonly called 'Cyclopean', was of polygonal character, sometimes roughly squared and built without

[1] Choisy, *Histoire de l'Architecture*, pp. 91–4, 97.

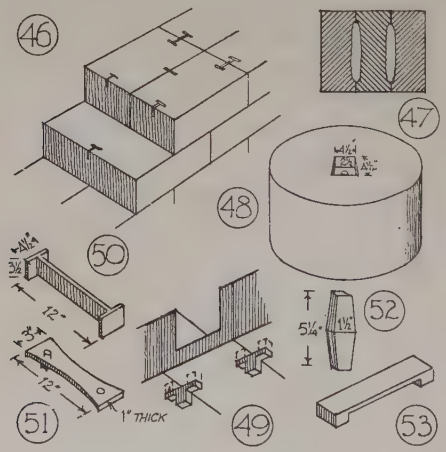
mortar. Enormous stones were used; thus the lintel of the Lion Gate at Mycenae is 16½ ft. long, 8 ft. broad, and over 3 ft. thick in the middle. Hard slabs were sometimes employed for facing. Wall-tiles were secured to the masonry by dovetailed-shaped bronze cramps. The ends of walls were often protected by wooden posts. The form of the corbelled Mycenean arch and vault is well known. But, on the whole, the masonry of these early periods in Greece was far inferior to that of Ancient Egypt.[1]

The stone used by the Hellenic Greeks was generally limestone—as at Olympia, Aegina, Paestum, and Corinth—or marble—as at Athens. Often a specially hard stone was employed for such exposed parts as the tops of cornices, &c. The system of walling followed one of three methods, either with all through-stones showing on both faces; or with through-stones every alternate course (Fig. 46); or with through-stones at intervals, ashlar-facing throughout, and a certain amount of rubble core. The last-named prevailed in the later or Macedonian period, and became general in the Roman period. The lowest course of the wall is usually higher than the rest, and is built in two thicknesses with a space between, thus anticipating the 'modern' damp-proof cavity-wall. Oblong stones were generally used at the quoins, and only in later work do we find stones rebated. Walls were always built dry, mortar never being used in ashlar work. Even in the best period the Greeks did not always lay stone on its natural bed. For

[1] *Ibid.*, pp. 228–32, 245–9; Hawes, *Crete, the Forerunner of Greece*, p. 30; Anderson and Spiers *Architecture of Greece and Rome*, pp. 15–16.

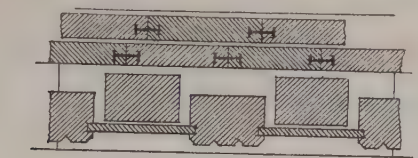
horizontal stone beams they often laid three stones abreast, thus facilitating handling and at the same time reducing the risk of failure due to a weak vein (Fig. 47).

The accuracy of the jointing in Greek masonry is wonderful. In the sixth century the whole of the bed was smoothed, in the fifth century only the edges. Thus the weight was carried on only a small part of the

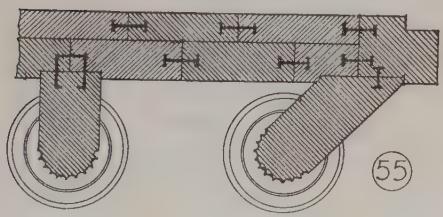


area of the bed, but that part was made sufficiently wide for its purpose. To prevent 'spalling' with such close joints, the edges were often rebated or V-jointed. Only the carvings of the metopes, triglyphs, &c., were worked on the ground. The drums of the columns of the Parthenon had very fine joints, obtained by rotating them on a bed of sand. Into each drum was cut a recess $4\frac{1}{2}$ in. square and $2\frac{1}{2}$ in. deep for a plug of cypress-wood, in the centre of which was a circular dowel used in revolving the drums.

Dowels and cramps (Figs. 50 to 53) were largely employed in masonry owing to the prevalence of earthquakes. Figs. 54 and 55 show their application in the frieze of the Parthenon and the columns of the Temple of Apollo at Bassae respectively. In the archaic period they are not found; in the sixth century wooden dowels were only used for the drums of the columns; but from



54



55

the fifth century in Greece iron fastenings of surprisingly 'modern' pattern, as the illustrations show, were systematically employed. The Greeks, as a maritime nation, understood the use of all sorts of tackle and lifting-appliances, but it is startling to find in the pages of Choisy a drawing of a Greek 'lewis' that differs in no way from the one we use to-day. Stones raised by this means were finally levered into position with a crowbar. Fig. 56 shows Cockerell's theory of the method by which the large stones of the entablature at the Temple of Jupiter at Aegina were raised into position, and Fig. 57

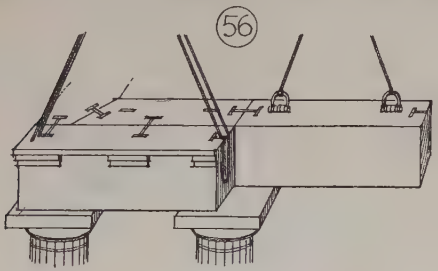
shows Hittorff's theory of rolling large stones up to the site in wooden 'cradles' stiffened with metal bars. Another method employed for raising and lowering the hard-stone drums of columns consisted in the use of *ancones* or 'ears' worked on the face of the drums, as the sketch (Fig. 58) shows. Apart from their marvellous skill in scientific stereotomy, the Greeks appear to have been competent and practical masons.[1]

Roman masonry closely followed that of the Greeks so far as ashlar work is concerned, but the Romans also evolved a form of building in rubble or concrete, so different from masonry proper that it is relegated to my next chapter under the head of 'Concrete'. Their system of building in ashlar had both a Hellenic and an Etruscan origin. From the Etruscans the Romans borrowed the barrel-vault and the joggled lintel, from the Greeks most of their other features. The Etruscans had used stone arches and vaults from very early times. The voussoirs of the Cloaca Maxima at Rome are in three rings, each 2 ft. 6 in. deep. They also constructed vaults corbelled out in horizontal courses, in the Mycenean fashion, and their masonry was either polygonal or squared.

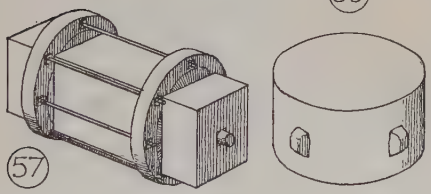
The three chief kinds of building stone used by the Romans are tufa, travertine, and peperino. The earliest known secular building of the Republican period, the Tabularium on the Capitoline Hill (78 B. C.), is built of peperino in blocks 4 ft. by 2 ft. by 2 ft. high, laid alternately as headers and stretchers, with a thin layer of mortar in all joints and a tufa core behind.

[1] Choisy, *Histoire de l'Architecture*, pp. 268–79; Anderson and Spiers, *op. cit.*, pp. 33, 39, 114; Simpson, *op. cit.*, p. 85.

Peperino is a hard volcanic stone, unaffected by fire, and quarried near the Alban Hills. Tufa is a soft stone which weathers badly, and was usually protected by stucco. The tufa blocks used in early work were usually 3 to 4 ft. long, 1 ft. 10 in. to 2 ft. high, and 1 ft. 9 in. thick. Travertine is a compact hard limestone, quarried



(56)



(58)

(57)

near Tivoli, and was useful where great strength was required, as in the voussoirs of arches. It makes an excellent lime when burnt, and this partly accounts for the durability of the Roman mortar and concrete to be described in Chapter IV. Some of the travertine blocks at the Colosseum are as much as 15 ft. long. The inner walls are of tufa and concrete with brick facing, and the vaults are in concrete. The Theatre of Marcellus is of travertine covered with hard white

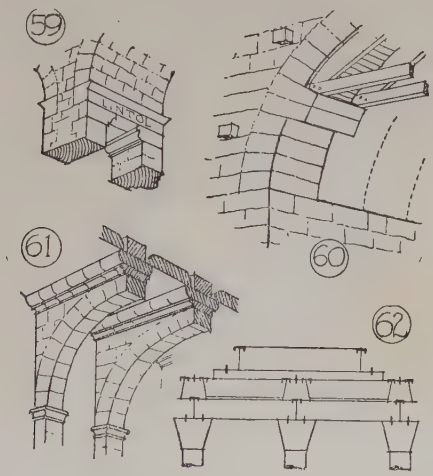
stucco to imitate marble. That the Romans understood the 'seasoning' of stone is clear from Vitruvius, who states[1] that if inferior stone is to be used, whether as rubble or ashlar, it should be quarried in summer and then exposed to the weather for two years. In cases where, as at the amphitheatre at Arles, great monolithic lintels bore the thrust of barrel-vaults, the Romans were quite prepared to lay stone on its wrong bed (Fig. 59), as the Greeks had done before them. In later times they imported enormous monolithic granite columns for use with their concrete vaults.

The Romans in their later work used dovetailed dowels for connecting ashlar blocks in successive courses, fixing them by running molten lead into the hole after the block was laid through a small channel in the lower stone. Much of their ashlar masonry was built dry without mortar, but mortar was used in their Syrian and African colonies. They seem to have understood the use of most 'modern' building appliances, so that part of the tenth book of Vitruvius reads like a modern treatise on scaffolding and tackle. For reasons of economy in timber they preferred the use of 'flying' scaffolds, resting on projecting stones (as at the Pont du Gard, Fig. 60), to tall structures resting on the ground. At the Pont du Gard no centering was employed for the lower part of the arches, the courses being built projecting. The vaults here are really a series of separate parallel arches, allowing of the centering being moved along from one to the other. Sometimes a vault was constructed of arches arranged in the same way but with spaces between which were covered with large

[1] Vitruvius, II. vii. 5.

stone slabs (Fig. 61). This was specially popular in late work in Syria, and is also found in the Baths of Diana at Nîmes.

Fig. 62 shows the construction and jointing of a typical Roman entablature for a colonnade, from the Temple of Jupiter Stator. Here each bay of the frieze consists of two blocks tapered upwards and carrying flat relieving-



arches or lintels. In light construction the Romans cut a whole entablature out of one block of stone. In their Pompeian buildings the whole work of the entablature was sometimes done by timber beams, the stone facing being merely decorative. Joggled lintels were occasionally used, as in the theatre at Orange, and at Spalato.

In regard to the scale of Roman masonry, it may be noted that the average height of the masonry courses

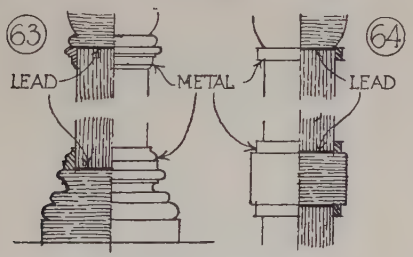
at the Pont du Gard, where no mortar is used, is about 2 ft. The famous *trilithon* at Baalbek consists of three stones, averaging 63 ft. long, 12 ft. high, and 11 ft. deep, with joints so fine that a small knife-blade cannot be inserted between them, while another stone lying near them measures 77 ft. by 15 ft. by 14 ft. The scope of this book does not include Roman groined vaulting in stone.[1]

The masonry construction of later buildings in Syria is extremely interesting, and shows a development from Roman methods. True arches were used, as well as lintels carved into arch form. The remarkable dome of the church of St. George at Ezra was built dry, without mortar. The method of building without mortar also prevailed in still later work in Armenia, where limestone was scarce.

Byzantine masonry is for the most part a development of the so-called Roman 'concrete' construction, as will appear in Chapter IV. Bricks were used alternately with stone courses in vaults and arches as well as in walling. Materials, especially marble columns, were rifled without scruple from older buildings, but these columns were now used structurally to an extent that the Romans had never dreamed of. The *dosseret* was invented to bring the shape of the vaulting springer down to that of the capital. The columns were often limestone monoliths, set on the wrong bed, or marble shafts, which were often split down the natural veins or fissures by the weight of the vaulting. To avoid this,

[1] On Roman masonry, see Choisy, *L'art de bâtir chez les Romains*, pp. 103–41; *Histoire de l'Architecture*, vol. i, pp. 513–20; Anderson and Spiers, *op. cit.*, pp. 121–2, 131, 134, 172, 198, 237–8; Simpson, *op. cit.*, p. 153; Vitruvius, II. vii.

bands of metal were frequently used around the neck and base of the shaft (Fig. 63). To lessen the risk of fracture by earthquakes, very prevalent in this part of Europe, a thin sheet of lead, usually about one-twenty-fifth of an inch thick, was laid at the same points, the metal bands preventing it from spreading outwards. Sometimes, in later work, columns built up of two or three drums were used, laid on their wrong bed, but with stone blocks laid on their natural bed at the point of



junction, and with metal bands and lead seating as before (Fig. 64). The most remarkable example of Byzantine masonry is the enormous lid or flat dome of Istrian stone, 33 ft. in diameter, covering the tomb of Theodoric at Ravenna.[1]

The Saracens in Egypt and Syria followed Byzantine tradition very closely in their masonry methods, as in the joggled voussoirs of the great gateways of Cairo, designed by an Armenian architect in the eleventh century. Although admirable limestone was to hand in the great Muqattam quarries outside Cairo, the Pyramids were stripped of their stone facings, and both

[1] On Byzantine masonry, see Choisy, *L'art de bâtir chez les Byzantins*.

pagan temples and Christian churches were despoiled to obtain materials for Muslim mosques. But the Egyptian masons of the fourteenth and fifteenth centuries proved themselves marvellously skilful in their use of stone; so skilful, in fact, that their delight in ingenious joggled joints in voussoirs and even in thresholds (Figs. 65, 66, 67) led them into wild excesses. From the Byzantines they borrowed the idea of polychrome masonry, using this as a counterchange to heighten the effect of their daring joggles (Figs. 66, 67). The equally startling masonry of their mosque-domes and minarets, as of their stone 'stalactites', is too complex to discuss in this book, but is treated in detail in my *Muhammadan Architecture in Egypt and Palestine*.[1]

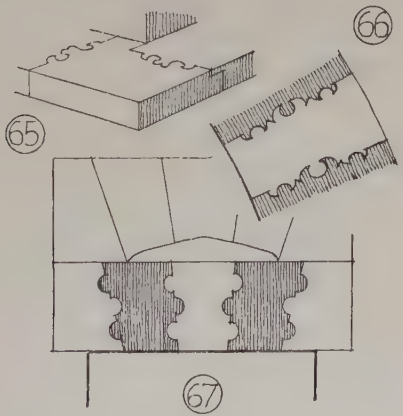
Romanesque masonry, on the whole, shows a marked decline from the work of the periods just described, but is probably not so bad as some writers have represented it to be. Viollet-le-Duc states that the Romanesque architects, far less skilful in controlling thrusts than their Gothic successors, relied more on mass, solidity, and sound jointing and workmanship. Sir Thomas Jackson, a great authority, does not agree that this applies to England, where he says that he has found 'the Early English masonry as good as the Norman, and the mortar much better'.[2] Certainly Saxon masonry in England is rough and unskilful, while the sketch[3] (Fig. 68) of a pier from S. Ambrogio at Milan, a famous Romanesque church, does not display any great know-

[1] *Op. cit.*, Chap. XI.

[2] Jackson, *Byzantine and Romanesque Architecture*, vol. ii, pp. 265–6.

[3] After Cummings, *Architecture in Italy*.

ledge of construction. Also one must admit that most Romanesque building is clumsily heavy according to Gothic standards (thus the thickness of the nave walls at Winchester Cathedral is 7 ft. between the buttresses), but generally that is simply because the builders trusted to mere mass to resist thrusts instead of balancing them by buttresses in the scientific and economical Gothic way. Rubble was commonly used for walling, and



often built without mortar. Where thin ashlar facing was used with a rubble core, there was a tendency to unequal settlement, caused by the greater number of joints in the rubble core. This fruitful source of subsequent trouble was avoided by the more expert Gothic masons of later days. Mortar, where employed, was used as a means of distributing pressure, as well as for its binding properties.

Polychrome masonry, beloved of the Saracens in Egypt, and probably derived from the Byzantine

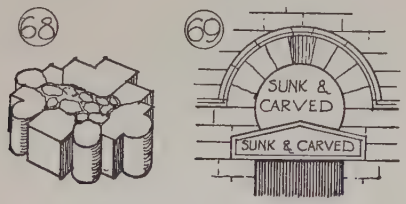
methods described in Chapter IV, was used in Romanesque times at Vézelay in France, at Lorsch near Worms, and at St. Peter's at Northampton, but especially at Le Puy and other places in Auvergne, where the materials employed were the local volcanic black basalt alternating with a yellowish-white freestone and with red brickwork. In England was evolved another fashion, destined to become a leading characteristic of our Gothic style, in which dark-coloured Purbeck or Bethersden marble shafts were contrasted with white freestone masonry.

The important question of Romanesque arches, vaults, and domes cannot be discussed here, but Fig. 69 shows the characteristic form of the lintel and tympanum, from the main portal of Notre-Dame du Port at Clermont-Ferrand (*c.* 1100). In this case, the quasi-horseshoe arch may have been derived from the Saracens, whose influence was strong in this part of France. In conclusion, it may be noted that the roughness and lack of finish found in most Romanesque buildings is due not only to ignorance on the part of the builders, but also to prevailing social conditions—the risks of the road, and, indeed, the lack of roads, as well as of security, making transport difficult and manual labour scarce. In this period began the practice of dressing all stone, as far as possible, on the ground, before building it into position.

Gothic masonry is so excellent as a rule—from the point of view of truthfulness, common sense, economical use of material, and above all of beauty—that one is apt to overlook its frequent shortcomings and to regard all medieval construction as above suspicion. But a careful examination of almost any Gothic building will

reveal examples of bad material and bad jointing. In spite of these exceptions, negligible compared with the whole achievement of the period, Gothic stands out even in advance of Greek building as the style in which masonry assumed its maximum importance, and in which it was most skilfully handled.

During the later Middle Ages transport was difficult and consequently expensive, while labour was plentiful and cheap. There was no wheeled transport to speak of, so that pack-animals had to be utilized where waterways were not convenient. These conditions explain the



extraordinary economy in masonry construction, and the comparatively small size of the stone blocks used, while the abundance of labour, coupled with the high level of craftsmanship ensured by the system of trade-guilds, explains the elaborate nature of Gothic mouldings and the profuse employment of carving. The size of the stone blocks, whether ashlar or rubble, allowed timber scaffolding to be utilized in a way that was impossible in the older countries around the Mediterranean where timber was comparatively scarce. From the ancients, however, was borrowed the use of metal cramps and dowels, adapted somewhat to the needs of lighter masonry construction. Mortar was plentifully

employed as a means of distributing weight as well as a binding medium, and care was taken to equalize the number of joints in facing and backing, so that unequal settlement was avoided. Difficulties of transport encouraged the use of local stone, even where this was not very durable; hence much subsequent decay and trouble. For the wonderful churches of Norfolk and the Fen districts, stone was imported by water from Stamford and elsewhere. Tufa was brought for vaulting to Canterbury in the late twelfth century from the Rhine or less probably from Italy, and large quantities of Caen stone were shipped from Normandy to England all through the Middle Ages.

Spreading footings, sometimes on a foundation of timber piles, marked another advance, though the medieval builders, being ignorant of concrete as we understand it, were incapable of designing foundations scientifically, as is done in modern practice. They did, however, often attempt to distribute the load of arcade piers by a system of low walls connecting their bases below ground (or, as at Salisbury, above ground), and occasionally similar lateral walls were used to tie the piers of the main arcade to the outer walls and buttresses. But a few instances cited by Sir Thomas Jackson prove how great and how many were the risks taken by Gothic architects in designing foundations. At Beauvais in the sixteenth century (though this is perhaps rather beyond the limits of the Gothic period proper) a vast tower was piled on piers which must have already been carrying at least 12 tons to the square foot. It fell within a few years.[1]

[1] Jackson, *Gothic Architecture*, vol. i, p. 130.

'There was bad building and scamping then as now. Not to go beyond my own experience, I have constantly been surprised by the carelessness of the old builders about their foundations. At Winchester they are laid on a peat bog and stand in water. Fortunately the walls are unusually well built for that time, or the settlements, dreadful as they were, would have been worse, and the cathedral would long ago have been in ruins. At Christchurch Priory the south side of the nave has had to be underpinned. At St. Cross the foundations are on soft wet ground, and serious settlements have taken place. At Ashbourne the subsoil is as bad as at Winchester, and the foundations are only of rough stone loosely piled together without any mortar. At Bishop's Waltham the footings are laid on the top of the ground which is clay. The mortar is often mere rubbish. The lovely Early English tower of St. Mary's at Stamford, to which Sir Walter Scott used to take off his hat when posting through the town northwards, is put together with nothing but dirt scraped off the road containing very little lime, if any. It is the same at the pretty little thirteenth-century tower and spire of Duddington a few miles away, and is probably no better in most of the fine churches of Northamptonshire. At Chichester, before the spire fell, the mortar of the interior ran out like water when a stone was withdrawn, and I am told it was just the same at Peterborough. For all these sins of our medieval masters we are now paying the penalty.'[1]

Among other instances mentioned by the same writer, there are some where the original design put the very utmost strain on the foundations and fabric generally (such as at the Doge's Palace at Venice,[2] where the top-heavy appearance of the solid upper part is a truthful indication of the constructional facts), and others

[1] *Ibid.*, vol. i, pp. 258–9.

[2] *Ibid.*, vol. ii, pp. 239–40.

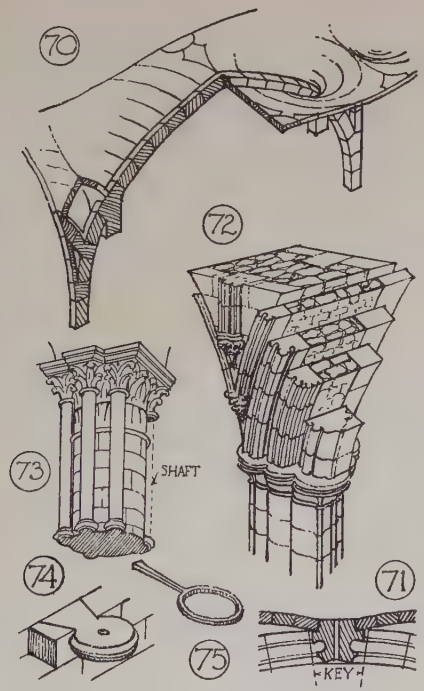
where later builders piled great loads, generally towers and spires (as at Salisbury, where the foundations are carrying 16 tons per square foot), on substructures never intended to bear such stresses, and often incapable of doing so.[1] These cases are mentioned here only to qualify the superstition that all building of the Middle Ages was inspired and perfect, but they do not in any way lessen our admiration of the marvellously high standard that was maintained as a rule, or the wonderful achievements that were safely accomplished.

The cutting of beds and of vertical joints was as carefully executed as the dressing of the visible faces. On the jointing depends much of the ultimate effect of any Gothic building. To realize this one has only to refer to some early Victorian book of measured drawings of Gothic details, where the joints are not indicated, and the consequent lack of effect is at once apparent. Hence the practice among many modern church architects of having the joints raked out has much to recommend it. Occasionally Gothic masonry was unsound in minor details also, as in the shape of the familiar 'water-holding base'. More often jointing was apt to be clumsy or unscientific, but generally joints were well placed, and nowhere is this more apparent than in tracery, especially in perpendicular tracery. Sir Thomas Jackson shows how soffit cusping gradually developed into solid cusping, an interesting example of the increasing skill of the mason.

Though the mysteries of vaulting cannot be discussed here, two sketches are given to show typical details of the masonry work involved. Fig. 70, adapted from

[1] Jackson, *Gothic Architecture*, vol. ii, pp. 88 *n.*, 92.

Willis, illustrates the method by which the deceitful stone pendants are fixed in the fan-vaulting of Henry the Seventh's Chapel, and Fig. 71 shows the construc-



tion of a boss or keystone at the crown of a groined vault. Such a boss was sometimes pierced to carry a lantern at festivals. The Gothic architects were not perhaps such jugglers in stone as their Saracen contemporaries in Egypt, but occasionally, as in the pendants of their fan-vaults, they were inclined to

disregard the proper limitations of their material in their pride of craftsmanship, and there are church porches in France where carved stone angels, in the attitude of horizontal flight, are suspended on metal hooks!

Polychrome masonry never attracted the Gothic masons of England and France, though the use of Purbeck shafts approximated to it. Even Mr. Bond admits [1] that in one cathedral the effect of these suggests drain-pipes; perhaps one would be more just in likening them to the heating-pipes often found in their neighbourhood. They were held in position by metal rings or bands built into the masonry, as at Salisbury (Fig. 75); or occasionally the stone annulets built into the column or the wall were pierced so that the shaft passed through them, but generally they were solid (Fig. 74). The marble shafts were laid (on their wrong bed) when the column, with its stone annulets built in, had settled after erection (Fig. 73). This settlement was due to its numerous joints, whereas the shafts, from annulet to annulet, were monolithic. But there are a few isolated examples of real polychrome masonry in this country, as at St. David's Cathedral, illustrated in Sir Thomas Jackson's book,[2] and a form of ornament closely akin to it is the use of flint and stone alternately, as at Southwold [3] and many other East Anglian churches. Abroad, the striped façades of many churches in Tuscany and Genoa reproduce in variegated marbles what the Byzantines originated in alternate bands of stone and

[1] F. Bond, *Gothic Architecture in England*, p. 252.
[2] Jackson, *Gothic Architecture*, vol. ii, Plate C.
[3] See my drawing forming the frontispiece to this book.

brick, while in Sicily may be seen much polychrome masonry that has a Saracenic rather than a Byzantine origin.

Fig. 72, my last illustration of Gothic masonry, shows the construction of an arch-shaft from the choir of Whitby Abbey, with a rubble filling. It exemplifies the logical advance from the simple stone arch with recessed orders of the Romanesque period to the more elaborately moulded but structurally similar Gothic form.[1]

It is not an abrupt transition from the masonry of the Middle Ages to that of those districts of England where traditional methods prevailed up to the end of the seventeenth century. The two chief districts are Yorkshire (including parts of Lancashire and Derbyshire), and the Cotswolds (including all Gloucestershire, most of Oxfordshire and Northamptonshire, and parts of Worcestershire). There were also stone buildings in Cornwall, Devonshire, Sussex, and elsewhere, but not of equal importance with those of the two districts mentioned.

The Yorkshire area is almost entirely hilly or even mountainous, and abounds in hard millstone grit, coarse in texture and difficult to work. But this stone was easily split into flags, which were used for roofing. Transport in this wild dale-country was of the worst, and labour could not have been plentiful, while the climate was rigorous. All these conditions are reflected in the style of the cottages and farm-houses erected from about 1550 to 1700 (Figs. 76 to 81). Walls of

[1] On Gothic masonry in general, see especially Choisy, *Histoire de l'Architecture*, vol. ii, pp. 259–347 and 370–1; also Bond, *Gothic Architecture in England, passim.*

rubble masonry at least 2 ft. thick were used, the courses 3 in. to 6 in. thick for cottages, with larger bondstones and large dressed quoins of irregular lengths. The roofing material being very heavy and the district subject to wild weather, the pitch of gables was usually very low, from 35 deg. to 40 deg. These low-pitched gables harmonize well with the gaunt fells and valleys among which they stand. The windows are small and low, often only one range of lights high, but of great length horizontally. Chimneys are of solid stone, generally square, often set diagonally, sometimes on small stone corbels, as in Fig. 76. The gable copings are of stone, square or moulded (Fig. 79), and no lead flashings are used. But though these houses are generally plain to excess, many of them possess details almost baroque in their wealth of fancy. Almost every one has elaborate finials at the spring (Fig. 78) and at the apex (Fig. 77) of the gables, these finials slightly overhanging the wall-face.[1]

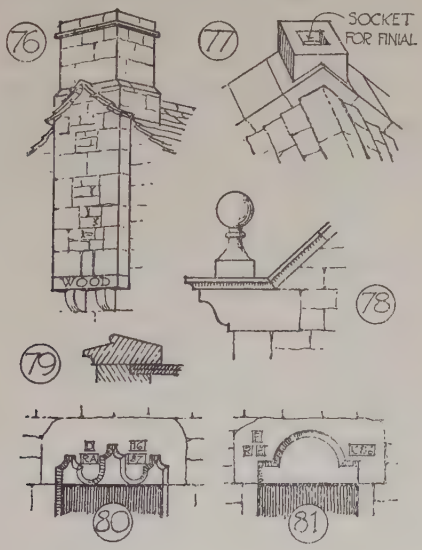
Sometimes in the first half of the seventeenth century elaborate traceried rose-windows are found.[2] But it is especially in the treatment of the lintels over the doorways that this craving for expression is evident, at times restrained, as in Figs. 80 and 81, at other times breaking out into a riot of originality that must have nauseated the Palladians of the day. This was undoubtedly 'modernism'.

From these Yorkshire heresies it is a great change to

[1] On the old stone houses of Yorkshire, see L. Ambler, *The Old Halls and Manor-Houses of Yorkshire*; G. Sanderson, *Architectural Features of the Settle District*; M. S. Briggs, *The Spirit of the Dales* (articles in the *Architect*, 1910).

[2] Ambler, *op. cit.*, pp. 78, 79, 82.

turn to the Cotswolds, where a more feminine and civilized style of building prevailed throughout the seventeenth century (Figs. 82–7). In this district is found an oolitic limestone, best quarried between April and October. From 1580 to 1690, the period when most of the houses with which we are concerned



here were built, the wool trade had made the Cotswold towns very prosperous, and the merchants of Burford and Chipping Campden were able to spend money on their churches and on their own dwellings. Thus the whole character of these houses is lighter, more graceful, and more refined than the rougher buildings of West Yorkshire, though the latter express admirably that spirit of the wild moorland that appears in the novels of

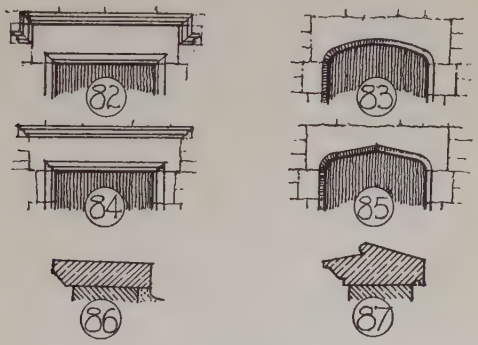
the Brontës. But construction was not always sound. The walls frequently had two faces with a rubble core, and often no foundations are used. The absence of gutters and down-pipes led to the dripping of water on the lower parts of the walls, which then decayed.

Usually walls were at least 18 in. thick, and more often 2 ft. thick or over. Either rubble stone in rather thin courses or ashlar masonry in rather thicker courses was used. Where the courses were from 2 in. to 6 in. thick, dressed stones were employed round doors and windows. Mortar joints were always wide. In Northamptonshire red ironstone and white limestone were used in alternate layers, recalling the polychrome masonry of Auvergne, Byzantium, and Saracenic Cairo. The walls of farm-buildings and of barns were often built dry, without mortar. The surface of the stone in ordinary houses was not dressed, but was either quarry-faced or roughly cut with a chisel. The floors were paved, as in Yorkshire, with large stone slabs, often in a geometrical pattern.

Over doorheads, lintels (not arches) were invariably used (Figs. 82 to 85), but these were often shaped to form arches, as Figs. 83 and 85 show. Windows were 12 in. to 16 in. wide and 2 ft. to 3 ft. high. Bays and oriels, hardly ever found in Yorkshire, were frequently used. Chimneys above the roof-level were square on plan, and were built of slabs of sawn and dressed stone, 3 in. to 4 in. thick and 8 in. to 10 in. deep, standing on edge and breaking-joint, with moulded caps. Mouldings were used also on mullions, dripstones, and elsewhere. Finials, panels, and other ornamental features were designed with the same freedom and originality as in

the Yorkshire examples, but always with a lighter touch. Gables were steeper, and roofs were covered with small stone slates in diminishing courses. Lead was never used for flashings, the stone slates being turned up under the copings with a flashing or fillet of mortar (Figs. 86 and 87).[1]

The rustic and vernacular architecture that has just been briefly described was essentially Gothic in spirit,



maintaining the tradition of the Middle Ages even after Inigo Jones had completed his Banqueting Hall and Wren had commenced St. Paul's. But the full force of the Renaissance had now reached our shores, and had borne fruit long before in Italy and even in France. It changed all our architectural forms, and altered the arrangement of all our buildings, except the minor cottages and farmhouses in remote districts; but can it

[1] On Cotswold masonry, see E. Guy Dawber, *Old Cottages of the Cotswold District*. Since writing the above, I have seen some fine houses of the same period in the Isle of Wight. Of these, Yaverland Manor, near Sandown, is perhaps the best example.

be said that any great alteration was seen in the craft of the mason?

Generally speaking, it may be said that the masonry of the Renaissance, though displaying good craftsmanship and external finish, lacked the variety and consequent interest of the less studied work of Gothic times. As has been pointed out in Chapter I, a great deal of rubbish has been written about the deadening effect on architecture of the professional architect, for, whatever they were called, there must have been men corresponding to modern architects in everything save their name in the Middle Ages, or our cathedrals could never have been built. An architect is primarily a man who lives by designing and supervising the erection of buildings, and Gothic buildings were so complex that they could not have been produced haphazard by any mere mason, however gifted. It is more correct to say that the architects of the Renaissance so exulted in the discovery of that rather uninspiring prophet Vitruvius, that they tended to attribute to Roman precedent and the copybook such importance that the craftsman became merely the means of turning the architect's ideas into stone, his 'not to reason why'. He thus lost much of the scope for initiative that he had had in such large measure in the Gothic period. Renaissance masonry is in no sense bad; on the contrary it generally displays a high degree of surface finish; but it is often dull just because it is 'correct', as of course it was intended to be. But whereas Gothic masonry commonly exhibits the main anatomy of its structure to the naked eye and gives one much satisfaction by so doing, buildings of the Renaissance, even the plainest

of them, are so clothed in the 'orders' that one's interest in their skeleton is seldom aroused. Hardly any text-book of Renaissance architecture concerns itself with constructional detail; except in regard to such special problems as the dome of St. Paul's and of other great churches, the writers are content to criticize the façades, and the methods of building are taken for granted. Yet the architects of the sixteenth and seventeenth centuries must have had to solve many practical problems for themselves, and Choisy tells us something of their work. From him we learn that the massive blocks of stone that form the frowning façades of such palaces as the Pitti and Strozzi at Florence, the Cancelleria at Rome, and several at Siena, are by no means what they seem, but are merely a comparatively thin facing applied to a wall of brick or rubble, with little or no bond to the backing. Thus at the Cancelleria the wall has a facing of travertine and dressings of marble. The wall was built first, then the facing was applied, and finally the window-dressings. (I remember watching a fine reproduction of a Bolognese palace rising in Cairo a few years ago. The walls were constructed of reinforced concrete, and afterwards a lining of thin bricks were applied to the façade. The ultimate effect was admirable, and recalled the work of Peruzzi at his best; but I still wish that I had not seen the building in course of erection.) A common method of applying stone string-courses and dressings to palaces of the Italian Renaissance is illustrated in one of Choisy's diagrams. Chases were left in the wall, and in the case of string-courses small brick pierlets were left to carry the brick facing above. The marble-

faced palaces and churches of the Renaissance, as of the Middle Ages in Italy, often were constructed with bricks projecting obliquely from the main body of the wall, and to these was bonded an outer facing to which the marble facing was applied. This followed the Roman practice illustrated in Figs. 87A and 87B.[1]

In France the use of brickwork in conjunction with stone dressings became popular during the Renaissance, but according to Choisy a proper bond between dressings and brickwork was always contrived. The same writer offers a possible explanation of the curiously shaped voussoirs of the early Florentine palaces, suggesting that they were made wider at the key than at the spring in order to avoid the acutely pointed spandrels that would have resulted had voussoirs of constant width been used.

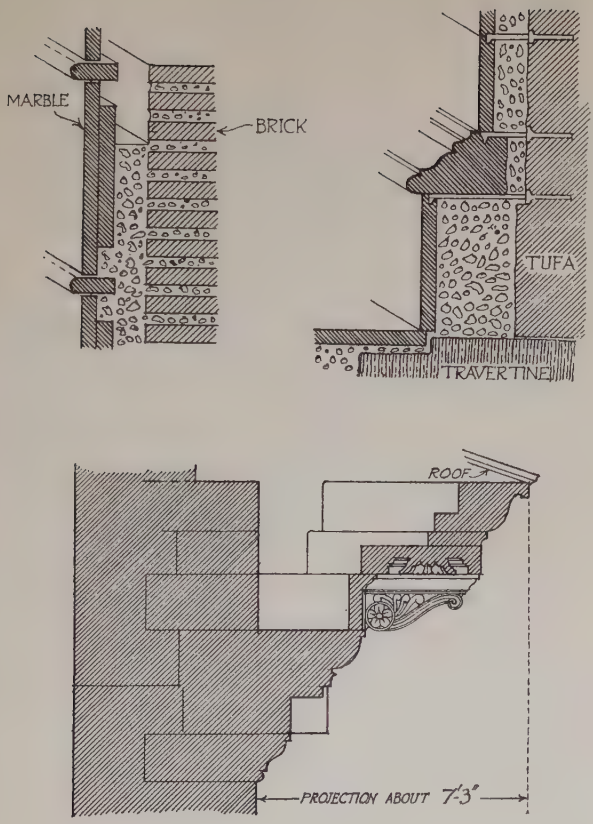
The coved ceilings characteristic of Italian Renaissance palaces were sometimes constructed of flat bricks, reliance being placed simply on the mortar, and rubble or even gravel being used as a covering; but often, especially in Genoa, they were made of plaster on timber backing, or of plaster on a backing of plaited sticks.[2]

Fig. 87C gives a section of the magnificent stone cornice of the Strozzi Palace at Florence, and makes it clear that its apparently enormous weight is greatly reduced by the method adopted in its construction.

The masonry of the Renaissance in England was generally excellent, and nothing has done more for Wren's reputation than the great success of his use of

[1] On Renaissance masonry in Italy and France, see Choisy, *Histoire de l'Architecture*, vol. ii, pp. 612–14, 679, 683, 703, 732, 742.

[2] Choisy, *op. cit.*, pp. 618–31.



Figs. 87A and 87B. Roman marble facing; 87C. Section of stone cornice, Strozzi Palace, Florence

Portland stone in the rebuilding of the London churches after the Great Fire. In conjunction with the silvery lead of their spires, this material adds to the beauty of every riverside view of the city. In some cases, of course, the stone has weathered badly, but as a whole it has justified the great architect's choice. Wren appears to have given much attention to all aspects of craftsmanship, and to have had the assistance of competent and enthusiastic masons.

In conclusion it must be remembered that the introduction of Portland and other fine limestones was partly dictated by the need for smooth surfaces and accurate finish in Classical buildings. The freedom of Gothic masonry was as abhorrent to the later Renaissance architects as the simple rusticity of the Yorkshire and Cotswold craftsmen must have been. Yet, in their lonely valleys, these rugged homesteads are far more at home than any formal Palladian mansion could be.

IV

CONCRETE

It does not appear to be proved that the manufacture and use of concrete, as we now understand it, has any historical basis; but before describing the famous Roman buildings in the earlier form of the material bearing the name, something may be said as to alleged concrete buildings of the remote past. Mr. W. N. Twelvetrees, in a very recent book,[1] claims that 'portions of concrete buildings have been discovered in Mexico and Peru, dating back to prehistoric times'. He also illustrates a fresco from the Temple of Ammon at Thebes,[2] which, he states, represents the making and use of concrete about 1950 B. C.

'Commencing at the left hand, we have the drawing of water from a lake, the slaking of lime in the first heap, and the digging of sand for the preparation of mortar shown in the second heap. The carrying of mortar and the making of bricks for facing the concrete core should also be noted, as well as the inspectors, two armed with rods, and one with a whip, for the persuasion of backward workers. Another feature showing how faithfully details are depicted in the fresco is the representation of mortar adhering to the feet and hands of the workmen. The building of a solid concrete wall faced with brickwork is illustrated in the lower part of the fresco, the story of which is told by the hieroglyph birds in the background.'[3]

[1] W. N. Twelvetrees, *Concrete and Reinforced Concrete*.

[2] *Ibid.*, frontispiece.

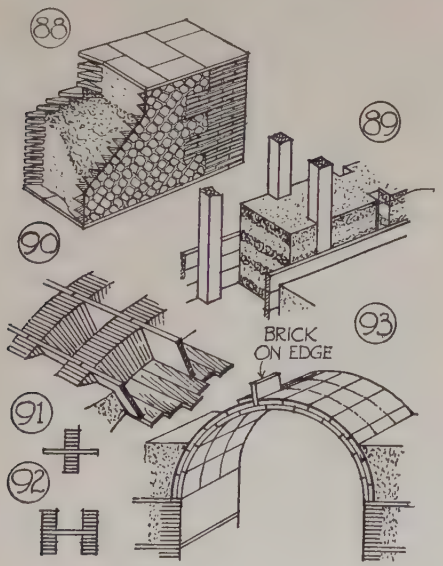
[3] It is very questionable whether this assumption can be justified. An eminent Egyptologist to whom I have referred this point states

The so-called ' concrete ' construction of the Romans dates back at least to Republican times. As applied to walling it consists of small stones and of lime mortar in alternate layers filled in between two outer facings of brick or stone *without falsework or centering*. This is only another instance of adaptability to circumstances, for falsework would have involved timber, and timber suitable for building was scarce in Italy. The outer facings took the form of (*a*) *opus incertum*, rough stones about 4 in. cube arranged on no particular system, this being the method described by Vitruvius (II. viii. 1) as ' the ancient style ', disused in his day, though he considers it stronger than *opus reticulatum*; (*b*) *opus reticulatum*, resembling the last, but with the stones arranged diagonally like the interstices of a stretched net; (*c*) triangular bricks, with a flush face to the exterior, thus giving a good indentation or bond with the core of the wall; (*d*) marble slabs, used as a lining internally in later work, as illustrated on Figs. 87A and 87B; and (*e*) masonry proper. Only with the last-named facing was ' tamping ' or ramming of the concrete core resorted to. At intervals of 5 to 10 ft. apart vertically, lacing-courses of thin flat bricks about 2 ft. square and 1½ in. to 2 in. thick, sometimes in double or triple layers, were used to bond the core with the facings. Fig. 88 shows *opus reticulatum* on the right and triangular bricks on the left, with lacing-courses and quoins of flat bricks.

The mass of the wall between the two facings was formed of layers of mortar 4 in. to 6 in. thick, composed

that the fresco represents the haulage of stone blocks up a ramp on a cradle.

of lime and pozzolana or of lime and coarse sand, alternating with layers of pebbles of compact tufa or black lava, such as are used for modern road repairs, and small enough to pass a 3 in. or 4 in. ring. The layer of small stones or pebbles was spread with a shovel, and



afterwards grouted to fill up the interstices. It was slightly thicker than the beds of mortar above and below it. The reason for using these small stones in filling does not appear to have been the ease of handling them, but rather because the proportion of mortar used in bedding them corresponded roughly to that used in bedding the facings, and so ensured equal settlement of facings and core. The volcanic rock used for this

work was very 'thirsty', and if used in large blocks would have absorbed all the moisture in the mortar, Vitruvius recommends[1] the use of small stones, apparently for this reason, and it seems that they were always wetted before being employed on the building. Vitruvius also has a chapter on pozzolana,[2] the volcanic product which when mixed with lime formed the strong hydraulic cement that accounted so largely for the durability of Roman 'concrete' walls and vaults. It will be seen that the process just described can in no way be regarded as concrete building as we understand it, in which a thorough incorporation of aggregate and matrix is an essential feature.

Tamping was used only for walls faced with strong ashlar, or for foundations which were filled in between boards fixed to posts about 3 ft. apart (Fig. 89), as appears from the evidence of remains. Scaffolding consisted of movable platforms carried on putlogs built into the walls, the holes so made being afterwards filled up. Other holes running transversely across the wall seem to indicate the frequent use of timber ties for binding together the two outer faces of the wall, a practice highly developed in later years by the Byzantines and the Saracens.[3]

Fig. 93A, based on Mr. F. W. Reader's drawing exhibited in the Guildhall Museum, illustrates a section of the Roman wall of London, with the later additions

[1] Vitruvius, II. vii.

[2] *Ibid.*, II. vi.

[3] On Roman concrete construction in general, see Vitruvius, II. vi, vii, viii; Choisy, *L'art de bâtir chez les Romains*, pp. 11–101; and *Histoire de l'Architecture*, pp. 521–30; Anderson and Spiers, *Architecture of Greece and Rome*, pp. 140, 183, 270–1; Simpson, *op. cit.*, vol. i, p. 184.

that were made to it in the Middle Ages. The lower (Roman) portion is formed of layers of ' concrete ' such as has been described above, filled in between two facings of squared stone blocks and strengthened at

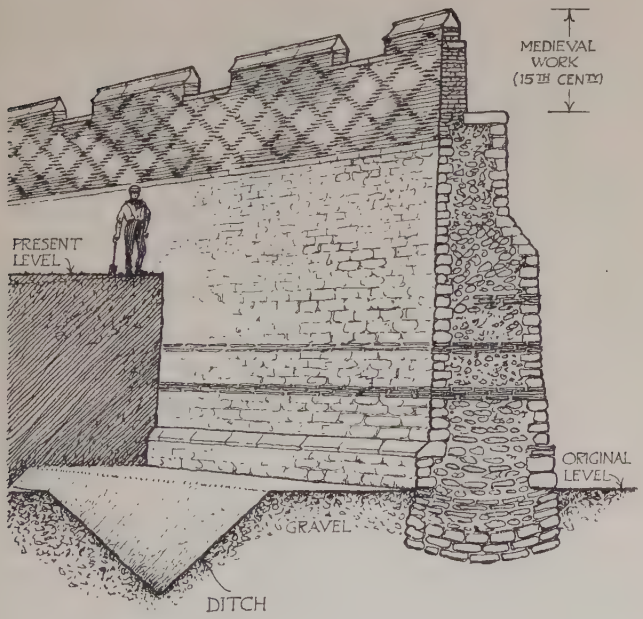


Fig. 93A. Section of the Roman Wall of London

intervals with lacing-courses of flat square tiles or bricks. It is of great thickness and rests on a concave bed of rough stones forming a sort of concrete. The flat bricks or tiles are about 18 in. by 12 in. by $1\frac{1}{2}$ in. thick, laid in ' Flemish Bond '. The total length of the wall, which had a chamfered plinth, was some two miles, and

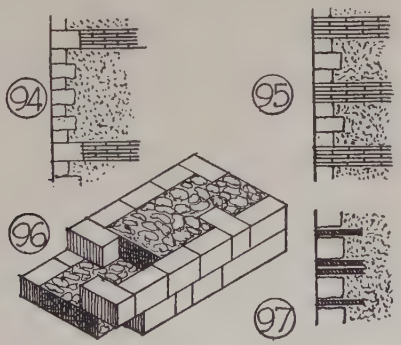
Professor Lethaby,[1] who has devoted much study to the remains, makes the suggestion that it would be interesting to have quantities measured of the whole work in order to estimate its amount according to modern standards. Certainly the labour of transporting the stone to London and dressing it there must have been enormous. Along the river-front—that is to say, where the north side of Thames Street now stands—the wall rested on a base of ' long and thick baulks laid crosswise, with piles beneath '.

In the construction of concrete vaults the Romans used exactly the same system of untamped horizontal layers that has been described above, and everything depended upon the homogeneity of the mass. Thus the function of the timber centering became important, and timber in Italy was scarce. Hence the evolution of brick skeleton arches to take the place of timber centering. These arches were either hollow, as in Fig. 90, or flat, as in Fig. 93. In the former case an arch-rib was formed in various ways, sometimes, as in my sketch, of flat thin bricks about 2 ft. square, at other times of bricks about 2 ft. by 6 in. This ' honeycomb ' rib was left hollow. In later building it was superseded by other and simpler sections (Figs. 91 and 92), the object being to economize brickwork; for though bricks were cheap, conscripted labour was cheaper still. A similar system was used for the ribs of concrete groined vaults. The flat vaults (Fig. 93) appear to have been designed solely for economy, and cannot be regarded as good construction. Generally two layers of bricks were used: the lower ones about

[1] W. R. Lethaby, *Londinium*.

2 ft. square and 1½ to 2 in. thick, the upper ones rather smaller. They were laid in plaster or in quick-setting mortar. At intervals bricks were placed vertically on edge to give a bond with the concrete mass, another brick being laid alongside to act as a 'cleat'.

Byzantine walls were built more or less on Roman lines, though sometimes the stones were laid diagonally. A great feature was the use made of brick lacing-courses (Figs. 94 and 95). In the first illustration the brick



courses are about 10 ft. apart and invisible on the face of the wall; in the second they are visible externally and are about 5 ft. apart. The mortar joints are as thick as, or often thicker than, the bricks themselves. Crushed tiles mixed with the mortar gave it a reddish tint. Choisy says that Roman and Byzantine mortar was no better than our best, but far better than our worst! (And Choisy had never seen a housing scheme.) Fig. 96 shows a method of ashlar facing for 'concrete' walls. Fig. 97 shows how bricks were often used in alternate courses, possibly for economy, perhaps with

some idea of bond, but probably to produce the effect of polychrome masonry which had been suggested to them by their use of brick lacing-courses in their rubble or 'concrete' walling. In Byzantine building the mortar joints were set back slightly from the wall-face, thus giving a sharp line of shadow under each brick or stone. Bonding-timbers were largely employed in walls to increase resistance to earthquakes, in one case forming a regular grillage in layers about 6 ft. apart, composed of longitudinal beams about $5\frac{1}{2}$ in. by $3\frac{1}{4}$ in. and transverse beams 7 in. by 4 in.[1]

In Gothic times the use of rubble walling continued, and a mixture of mortar and stone was sometimes used for foundations, but the scientific proportioning of lime or cement with sand and an aggregate does not seem to have been invented until comparatively recent years. This only is what is properly meant by 'concrete', and, admirable as were many of the mixtures of mortar with brick or stone that the Romans employed on their wonderful buildings, they are in a class apart. Thus the use of masses of rubble and mortar at Salisbury, Ely, St. Albans, Peterborough, Westminster, and other great medieval churches, has been cited[2] as evidence of the antiquity of concrete work; and other supposed instances are recorded in Fra Giocondo's Pont Notre-Dame at Paris (1507),[3] and elsewhere in France of the Renaissance.[4]

[1] On Byzantine rubble or concrete walling, see Choisy, *Histoire de l'Architecture*, and *L'art de bâtir chez les Byzantins*.

[2] Godwin, Essay on *The Nature and Properties of Concrete* (1836).

[3] Cited in Sauval, *Histoire*, vol. i, p. 228 (1724).

[4] On medieval use of rubble masonry, see Choisy, *Histoire de l'Architecture*, vol. ii, pp. 142–60 and 259–347.

But some architects are apt to forget that a new material need not be decried just because it is new, and frantic efforts to prove that its origin can be traced to the remote past are both undignified and impolitic. As these chapters bear witness, the builders in the great periods of history welcomed novel materials and methods as they were invented. The architect of to-day is expected to be something more than an archaeologist.

It is stated that George Dance in 1770, 'having to sink the principal foundations of Newgate Prison to a depth of 40 ft., in consequence of their site being partly on the ancient ditch of London Wall, threw into the bog cartloads of whole and broken brick and cartloads of mortar in the proportion of 1 to 4', but, although this made a good foundation, it was not what we mean by concrete. Half a century later Sir Robert Smirke, in forming the foundations of the General Post Office in St. Martin's-le-Grand, used layers of stones grouted with mortar, not at all unlike the Roman method, and some of Soane's buildings had foundations of the same sort. A mixture of Kentish ragstone and liquid mortar was filled in between the heads of the piles on which Waterloo Bridge was built in 1811.[1] Apparently the name 'concrete' was first applied to building processes about 1820 or 1830, and in 1836 the R.I.B.A. published Godwin's prize essay on *The Nature and Properties of Concrete*. The historical survey with which it opens is of no great value, as most of his examples are instances of the use of rubble and grout such as I have already cited. More important is the light which he throws on the practice of his own day. A common

[1] Godwin, *op. cit.*

mixture seems to have been 1 part of Dorking lime to 4–12 parts of Thames ballast, Kentish rubble, or broken granite. 'They are sometimes mixed together, slaked as mortar, and thrown into the foundation from a certain height; sometimes the ballast is laid on the site of the intended erection, and the lime poured over it in the shape of grout; while at other times the spaces to be concreted are filled with water, and the lime and ballast having first been mixed in the proper proportions, are thrown into it dry.'

It will be noticed that he does not regard the mixing of the ingredients (including water) *prior to laying* as an essential part of the process. And in 1847 General Pasley, in a book on *Limes and Cements*, speaks of a sea-wall recently constructed at Brighton as being, to the best of his belief, the first application of concrete other than for foundations. During the second half of the nineteenth century concrete proper came into general use, and its manufacture steadily improved. So far, we have been solely concerned with lime concrete, but the discovery of Portland Cement revolutionized the use of concrete for all purposes, and may be said to constitute the most important innovation in building during modern times. It was originally patented by Joseph Aspdin, a Leeds bricklayer, in 1824, but is said to have been invented by him in 1811. Its misleading name is supposed to have been derived from the fancied resemblance of the material, when mixed with sand, to Portland stone. Continuous improvements in the organization of its manufacture have given us to-day a product which is immeasurably superior to the excellent mortar made by the Romans, and possesses certain

properties, such as that of setting under water, of which their cement was incapable.

Finally, the last fifty years have seen, in the scientific combination of steel and cement-concrete, a new development that bids fair to alter the whole aspect of modern building. Architectural writers are at one in holding that the ultimate future of design in reinforced concrete is full of possibilities, and calls for all the genius of the younger generation. It is equally certain that we shall never solve this problem by a slavish following of the past, for it is a problem that has never been faced before. But a study of building methods in the past shows a readiness to accept and develop new inventions that should be an inspiration to us of a later day.

V

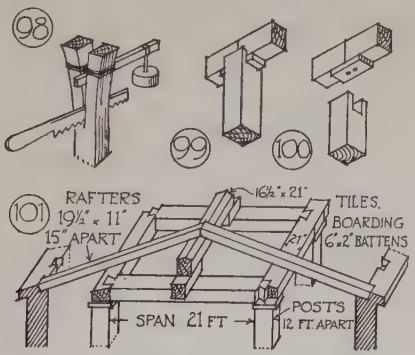
CARPENTRY

In the architecture of Ancient Egypt carpentry played a minor role owing to the shortage of timber. At one time this scarcity was less serious than it is now, as afforestation was practised, but, of the species of timber available, date-palms furnish wood which is fibrous, difficult to handle, and liable to failure under stress; sycamore is neither very strong nor supple; and of acacia and tamarisk it can only be said that they are the least unsuitable of native trees for building purposes. Timber was, however, largely used before stone became the general building material, and the architect or master of the works was styled 'the royal axe-man'. The tools employed had bronze blades up to the sixth century B.C., when iron came into general use. For felling trees a hatchet was used, for conversion into planks a saw, the trunk being fixed vertically in the ground, and the saw-cut kept open with a counter-weight (Fig. 98), showing that even the Egyptians economized labour on occasion! Most of the joinery work was executed with an adze or a chisel. (At first, according to Sir Flinders Petrie,[1] the adze was about $\frac{1}{2}$ in. wide, and the tiny bar-chisels were sharp at each end and held between the fingers.) 'The sawing of boards gradually began, with large wide knives notched on the edge; these led to the use of saws with regular

[1] W. Flinders Petrie, *Social Life in Egypt*, p. 144.

teeth by the fourth dynasty.' Surfaces were smoothed with sandstone or pumice. Holes for pegs were drilled.

Among ' modern ' joints used in these early days were various forms of mitre, the dovetail, the dovetailed tenon, and the tenon secured in a mortise with a wooden peg or pin. Wall-plates were halved over the supporting posts and pinned (Figs. 99 and 100). There is evidence that the Egyptians understood the principle of triangulation in carpentry, though this principle does not appear



again until Roman times. Planking 2 in. or $2\frac{1}{2}$ in. thick, on heavy beams 10 in. by 7 in. or more, was employed in forming floors and flat roofs. Enormous gates were fixed between the pylons at the entrance to great temples such as Karnak. Professor Petrie states that in the royal tombs beams 10 in. square and 18 to 20 ft. long were used. He also describes a form of construction employed in royal palaces, where planks were set upright, ' overlapping at the edges, and bound together through slots ', thus allowing for expansion and contraction in the wide range of temperature and the

heavy dews that occurred there. Although it is a difficult question, as yet unsolved completely, there is no doubt that timber forms largely influenced later Egyptian architecture in stone.[1]

In Assyria palm-trunks were much used, but beams of cedar were imported at great expense for the ceilings of palaces. In these, as in the later Persian and Sassanian buildings, roofs and ceilings only differed from the primitive construction of palm-trunks in being of better material and workmanship. Wooden prototypes undoubtedly had an effect on the development of Persian architecture.[2]

In pre-Hellenic Greece carpentry was practised, for Homer refers to the axe, the auger, and the toothed saw; but it was chiefly restricted to shipbuilding till the discovery of iron made its use more possible. Most of our knowledge of this period is due to the rock-cut tombs of Lycia, which reproduce timber forms in stone. The feature of Lycian carpentry was the short lengths of timber employed, for the trees that grow on the steep Lycian slopes have gnarled boles and twisted trunks. Wooden clamps and cotter-pins were freely used, and the result is very like English or French 'half-timber' construction.[3]

Greek carpentry is known to us only by descriptions. Fig. 101 shows Choisy's restoration of the fourth-century roof of the Arsenal at the Piraeus, a method similar to that employed by the Etruscans and the

[1] On carpentry in Egypt, see Petrie, *Arts and Crafts of Ancient Egypt*, pp. 137–9; Choisy, *Histoire de l'Architecture*, i, pp. 3–7.

[2] For Assyria and Persia, see Choisy, *op. cit.*, i, p. 91.

[3] For primitive Greece, see Choisy, *op. cit.*, i, pp. 227, 248–55.

Phoenicians. It will be noticed that this is a very primitive form of trabeated construction, perhaps derived from masonry prototypes, certainly followed in stone in later years. The surface of the roof was tiled. In some cases there was a boarded ceiling beneath. Terra-cotta facings were used on the sixth-century temples at Syracuse to protect the ends and sides of the timber framing. At Olympia the original entablature and columns of the Heraion were of timber, gradually replaced by marble.[1]

Vitruvius [2] gives his views on the felling and use of timber, according to Roman practice in his own day. He says that it should be felled in winter, before the sap rises in the spring. The best building timbers are oak, elm, poplar, cypress, and fir, but 'oak has not the efficacy of fir nor cypress that of elm'. Fir is light, rigid, straight in grain, inflammable, and decays easily. Oak is also liable to decay. Alder is good for piles, and is used for that purpose under all the buildings at Ravenna. Cypress and pine are very durable. Cedar and juniper are also good timbers, the former often used for coffered ceilings. Cedar is obtained from Crete, Africa, and Syria. Larch is fireproof. He adds that the best fir in Italy is obtained from southern rather than northern slopes, being more free from sap. In many respects his statements are at variance with modern ideas, particularly in regard to the alleged defects of oak.

He mentions the parts of a roof, but the documentary evidence on practical details is not very clear, and no

[1] On carpentry in Hellenic Greece, see Choisy, *op. cit.*,' i, p. 279–82; Anderson and Spiers, *Architecture of Greece and Rome*, pp. 21, 74.

[2] Vitruvius, II. ix.

original Roman carpentry remains to us. Choisy illustrates several conjectural Roman roofs, and Figs. 102, 103, and 104 are based on his drawings. Fig. 102 represents a simple span-roof over a shed at Pozzuoli, with no joints whatever except perhaps the halving of the rafters at their intersection. Fig. 103 is from Carlo Fontana's drawing of the double trusses used at Old St. Peter's as built in the time of Constantine. This shows iron straps, pegs, or pins at all joints, a king-post common to the two trusses, and a scarfed tie-beam. It is in all respects a great advance on the Greek roof illustrated in Fig. 101. It was only by using these double trusses that the Romans contrived to roof such wide spans as at the Basilica of Trajan (75 ft.) or at the Basilica at Fano (60 ft.).[1] Fig. 104 represents the roof described by Vitruvius [2] for the four sides of an open court in a Tuscan house. Messrs. Anderson and Spiers illustrate [3] a wonderful Etruscan rock-tomb at Corneto, imitating in stone the carpentry construction of a heavy hipped roof, a remarkable type to find at so early a date.

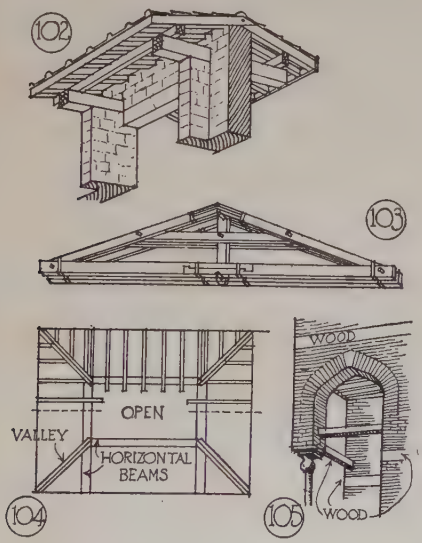
In introducing into their northern colonies these low-pitched roofs with deep eaves, so eminently suitable for the climate of Italy, the Romans showed a lack of the practical sense that generally characterized their building. But they were practical in the precautions that they took to isolate possible outbreaks of fire by carrying up solid stone walls between various portions of the

[1] On Roman carpentry, see Choisy, *op. cit.*, pp. i, 531–4, and *L'art de bâtir chez les Romains*, pp. 143–60; Anderson and Spiers, *op. cit.*, pp. 123, 178, 188; Vitruvius, II. ix.

[2] Vitruvius, VI. v.

[3] Anderson and Spiers, *op. cit.*, p. 123.

roofs of large buildings. They also took pains to avoid dry rot by ventilating the ends of timber beams and trusses. Wooden roofs were used chiefly by the Romans for their early temples and in the basilicas of the late period. The great Thermae of the middle period were roofed in concrete, in which case the Romans appear to



have considered the addition of an inflammable timber roof as illogical. The use of metal in Roman roof-construction will be touched upon in Chapter VII.

Little is known of Byzantine roof-construction in timber, the domical form being far more usual. A primitive span-roof of low pitch was used for basilican churches, following Roman tradition. The Dome of the Rock at Jerusalem, a building almost Byzantine in

character though a Muhammadan work, had a remarkable double dome of timber, perhaps suggested—as Choisy thinks—by the principles of naval carpentry.

Timber tie-beams were largely used to resist earthquake shocks, and to add rigidity to the structure during the first settlements of the vaults on their slender supports. Most Byzantine arcades are strengthened by tie-beams of timber, or (e. g. at St. Sophia) of iron. Usually these ties are placed at the level of the top of the dosseret, but sometimes a second is found near the top of the arch. If intended to be permanent, and if visible, they were often carved. Ties were also used for barrel-vaults, groined vaults, and domes, disposed in each case according to its requirements.[1]

The Saracens in Egypt were hampered by the scarcity of timber already noted as prevailing in that country, but it is known that afforestation was practised in the eleventh century. As early as the seventh century timber for building was imported to Mecca from India, and to Jerusalem from Cyprus. Oak and pine were imported to Cairo from Turkey in later years, as well as many other woods used for the elaborate joinery of the fourteenth and fifteenth centuries (see Chapter VI). For dwelling-houses and inferior buildings palm-trunks were used in the construction of flat roofs, as from the earliest times to the present day. The original roof of the Great Mosque at Damascus followed the ordinary Roman basilican type. The mosque of Ibn Tulun at Cairo (ninth century), already mentioned, still retains its flat roof of earth, lime, and slabs, resting on sycamore

[1] On Byzantine carpentry, see Choisy, *L'art de bâtir chez les Byzantins*, pp. 115–22, 143–7.

planks supported by heavy beams carried on corbels. The underside of the beams and the spaces between were lined with panelling. In the dry climate of Egypt timber lasts remarkably well. The heavy doors of this mosque were pivoted on stout wooden pegs, about 3 in. in diameter, let into a wooden head or lintel 2 in. thick. Many of the later madrasahs, or collegiate mosques, had flat timber roofs. Tie-beams were very largely employed in the arcades of the mosques, in conjunction with carved wooden plates or dosserets just above the capitals. Fig. 105 shows how tie-beams were used to strengthen brick houses of the Turkish period in the Delta towns.[1]

In Romanesque architecture, in certain countries only, wooden tie-beams were similarly used, especially in walls carrying barrel-vaults, where they were embedded at the springing level. Timber was very widely employed for the whole structure of dwelling-houses, which owing to the nature of their material have long since perished, though at Greenstead in Essex there still stands a small church built after the fashion of a Swiss chalet, of tree-trunks resting on a wooden sill, which is commonly held to date back to Saxon times.

Romanesque architects often used arches where we use roof-trusses, walls being carried up from the arches to the underside of the roof-timbers. (In the same way, the purlins of small modern houses are generally supported on internal walls or partitions carried up for the purpose, not on trusses.) But very few examples of these arches remain. In the rainy climate of Northern

[1] On Saracenic carpentry, see M. S. Briggs, *Muhammadan Architecture in Egypt and Palestine*, pp. 203–8.

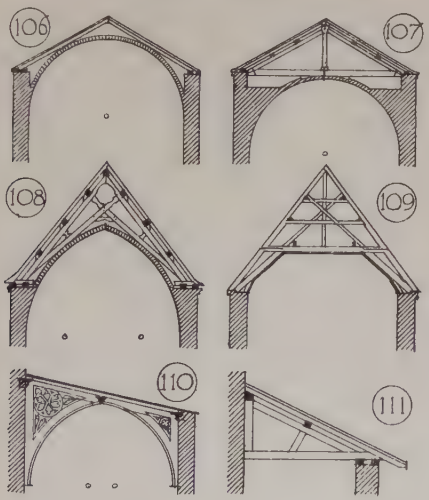
Europe it was necessary to protect the upper surface of the rubble vaulting, whereas some Roman concrete vaults had probably been left exposed to the weather. At first this was done by means of rafters supported at their centres on the back of the vaulting (Fig. 106). However, this method had obvious disadvantages, so it was replaced by a tie-beam roof as shown in Fig. 107, or by some other alternative. Hips were never used, as they involved more difficulties than simple gables. The flat Roman pitch was gradually increased to meet climatic conditions, but was never more than 45 deg.[1]

Carpentry of the Gothic period may be roughly classified as roofs and half-timber work, but these were sometimes so closely allied as to form one structure (i. e. in the old English and French barns). The Gothic roof was invariably of steep pitch, never less than 45 deg. (except in late Perpendicular work), and usually much more, sometimes more than 60 deg. The roofs over the aisles of churches were of flatter pitch than this in many cases. The timbers of roofs over vaults never rested on the vaulting. From the notes of Villard de Honnecourt it appears that in France the piers of the main vaults were built up to the springing, then tied in with temporary wooden ties, the timber roofs were next erected and covered in, and lastly the vaulting itself was constructed.

A further development of the roof over a stone vault is illustrated on Fig. 108, with diagonal braces and no tie-beam (a French example from Viollet-le-Duc). The next type included a tie-beam just above the crown of the

[1] On Romanesque carpentry, see Choisy, *Histoire de l'Architecture*, vol. ii, pp. 160–3.

vault, the diagonal braces being retained. This type was in use up to the middle of the fifteenth century. Fig. 109 illustrates the timber roof at Peterborough, which has a wooden ceiling. Aisle-roofs were generally of simple character. Fig. 111 shows an early French example,[1] and Fig. 110 a more ornate type (characteristic of East Anglia), from New Walsingham.



These timber roofs over stone vaults were of very similar nature in France and England, but it was in England that the Gothic timber roof attained its greatest beauty. We may accept Brandon's classification:[2] (i) roofs with tie-beams; (ii) roofs with trussed rafters;

[1] On Gothic timber roofs, see Choisy, *Histoire*, vol. ii, pp. 321–38 and 530–3.

[2] Brandon, *Open Timber Roofs of the Middle Ages*.

(iii) roofs framed with hammer-beams and braces; (iv) roofs with braces, or with collars and braces. Of these only the simplest forms can be described and illustrated here. Generally speaking, it may be said that, right into the seventeenth century, hammer-beams were characteristic of the eastern counties, roofs with trussed rafters of Kent and Sussex, and wagon-shaped roofs of the west of England.

Fig. 112 shows an ingenious adaptation of the tie-beam type, from North Walsham Church in Norfolk. Here intermediate trusses were used. The tie-beam roof in various forms persisted through all periods from Norman to Perpendicular, and is, of course, the only form that is structurally sound. The constant attempts all through the Middle Ages to avoid the use of tie-beams were dictated either by a desire to improve the internal effect of the church or hall (and especially to enhance the view of the two great windows in the gables), or perhaps by the difficulty of obtaining timber of sufficient length. But all the expedients employed, beautiful as the effect produced often was, are more or less indefensible.

Figs. 113, 114, and 115 illustrate varieties of the trussed-rafter type, of which Ely Cathedral furnishes the most important historical instance. The first shows the roof over the south porch of Heckington Church, Lincolnshire, covered with lead on boarding. A carved wall-plate is used, and the rafters are fixed 14 in. apart. This type is generally restricted to small spans, as, if the tenons and pins fail, the rafters open and spread, overturning the supporting walls. Fig. 115 shows the roof over the nave and aisles at Long Stanton Church,

Cambridgeshire. Here thatch is employed for covering and the rafters are 12 in. apart. Fig. 116 shows the roof over the nave of Lympenhoe Church, Norfolk, also thatched, with rafters 21 in. apart. The solid character of the rafters will be noted. This type of roof was frequently ceiled with boarding, ornamental ribs and bosses being used.[1]

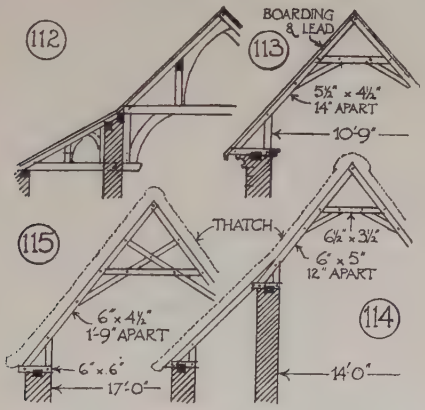


Fig. 116 shows a favourite type of roof with curved braces and a collar fixed about two-thirds of the distance from wall-plate to ridge. This, though better than a roof with no horizontal tie at all (e. g. the transept roof at Ely, which has only survived because of the thickness of the Norman walls on which it stands), tends to throw too much strain on the tenon-joint and the pin securing it. In modern adaptations of this type, wrought iron threeway straps are used to secure the collar to the

[1] These descriptions are abbreviated from Brandon, *op. cit.*, and Figs 114–17 are based on ilustrations in that book.

principal rafter, in addition to the tenon-joint. It should be noted that the brace is carried down the supporting wall on to a corbel, thus distributing the stress in the proper direction. This example is from the hospital of St. Cross, and is based on an illustration in Sir T. G. Jackson's *Gothic Architecture*.[1]

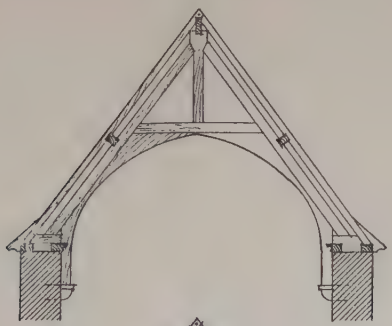
The hammer-beam roof (Fig. 117), a type peculiar to England, was an ingenious attempt to counteract thrusts which should be met by a tie-beam. (It should be remembered, as has already been noted, that a tie-beam does ruin the effect of the great east and west windows of a Gothic church, as seen from within.) Sir T. G. Jackson defines the hammer-beam as

'an imperfect tie-beam of which the middle part has been removed'. . . . 'The principal framed into it tends to drive it outwards, but this is resisted by the strut below, which presses firmly against the jack-leg, and so brings the thrust lower down the wall, where superior weight comes into play to steady it. From the point G, thus fortified, an upright post is framed into the principal, and from it spring curved struts to the collar, which is often hung up by a king-post to the ridge.'[2]

But if one can forget their structural imperfections (for many of the most famous and beautiful hammer-beam roofs have had to be strengthened by iron tie-rods), there is no denying that such celebrated examples as the Halls at Westminster and Eltham are among the finest instances of medieval carpentry in this country, the former enormous roof having stood for hundreds of years without further damage than is due to the serious

[1] Sir T. G. Jackson, *Gothic Architecture*, vol. ii, Fig. 174 D.
[2] *Ibid.*, p. 125. Fig. 117 is based on Fig. 174 E in the same work.

inroads of the death-watch beetle. In regard to the almost equally renowned roof over Wolsey's hall at Hampton Court, it is remarkable that its double slope anticipates the external form of the so-called 'Mansard'



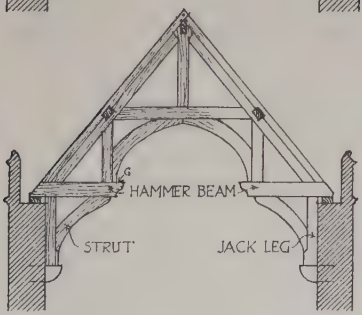


FIG. 116. Curved brace roof
FIG. 117. Hammer beam roof

roof in France, named unjustifiably, as appears below, after a famous architect of the Renaissance.

In many medieval roofs one finds 'wind-bracing', plain or cusped, let into the purlins and principals in order to diminish the bearing or span of the former. As with many Gothic expedients, this bracing is so

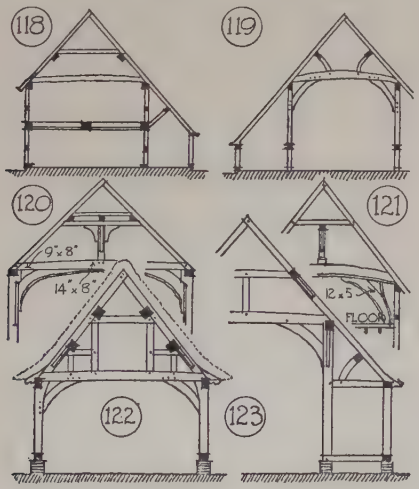
treated as to add to the general rich and flowing effect of the open roof.

Fig. 118 [1] shows the commonest type of roof in the cottages of Surrey, with a so-called 'skilling' or lean-to shed at the side. This might date from almost any period, but such examples as the Guest House at Lingfield (Fig. 120) [1] and that from a house at Godstone (Fig. 121) are of the definitely medieval character that lasted into the seventeenth century in places where tradition was not interfered with. In the old English barns the roof forms an organic whole with the framing of the low 'walls' and the posts which divide the whole structure into nave and aisles. Figs. 119, 122, and 123 show three roofs of barns at Wipley Farm in Surrey, Stone in Bucks., and Harmondsworth in Middlesex respectively. It is remarkable that the first named, in spite of its Gothic character, has hipped gables. In his admirable book, *The Development of English Building Construction*, Mr. C. F. Innocent devotes several chapters to the story of primitive construction in timber-framing, and illustrates numerous examples, mostly from barns in the south of Yorkshire.

Half-timber work, as it is commonly called, is found in all the countries of Northern Europe, where timber is plentiful. In France, where oak was generally used for carpentry, half-timber work seldom displays the curved braces beloved of English craftsmen (especially in the West Midlands), probably because English oak yields curved timbers more readily than do the tall, straight trees of the French forests.

[1] Figs. 118–20 are based on illustrations in Curtis Green, *Old Cottages in Surrey*.

The half-timber work of Kent, Surrey, and Sussex dates for the most part from the sixteenth and seventeenth centuries, and is chiefly of a very simple type. Oak was the normal timber, but elm, beech, and sweet chestnut were occasionally used. Fig. 124, based on a sketch by Mr. Curtis Green,[1] shows the principle of this form of construction. Mr. Guy Dawber, in his book



on *Cottages in Kent and Sussex*,[2] describes the methods ordinarily employed. Heavy story-posts, about 8 in. or 9 in. square, were let into a sill-piece resting on a low brick or stone foundation-wall. Those at the angles were larger, and were formed of the butt of a tree placed root upwards, with the top part curving diagonally outwards to carry the angle-posts of the upper story.

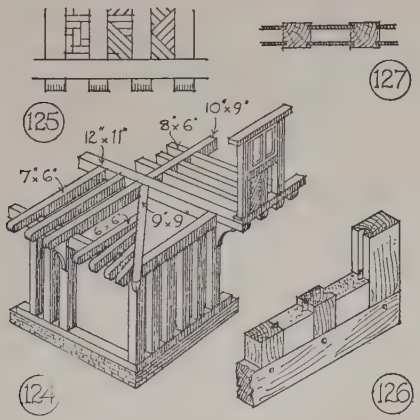
[1] Curtis Green, *op. cit.*, Fig. 33.
[2] Dawber, *Old Cottages in Kent and Sussex*, pp. 7–8.

Across these were laid beams projecting about 18 in. in front of the framing below, those at the angles being laid diagonally and showing in the rooms inside. Into these beams others were connected longitudinally, and to the latter were tenoned floor-joists, projecting the same distance as the main beams. In the sixteenth century the ends of the joists were covered with a large and deeply moulded fascia, but in later examples this was discarded and the ends of the joists merely rounded off. The framing of the upper story followed that of the ground floor, the plate and the sill being laid on the ends of the overhanging timbers. The house in its first stage was merely a timber skeleton, which, until the framing was well advanced, had to be propped and stayed from outside. In many houses the slots to receive these stays are still visible in the larger timbers on the ground floor. The spaces between the main posts were filled in with uprights 8 in. or 9 in. wide, and about the same distance apart. Only in later work were they spaced more widely, and curved timbers introduced.[1] The space between was 'then filled in with wattles or laths, and chopped straw and clay, and the surface plastered flush with the woodwork' (Figs. 127, 197). Sometimes the whole surface, even the timber framing, was plastered over in later years (Fig. 198). For filling the spaces between the timbers, brickwork was often used (Fig. 125) and in one notable instance, at Great Chalfield Manor House in Wiltshire (Fig. 126),[2] stone was employed for the same purpose.

[1] See my drawing facing p. 1 of this book.

[2] Based on a sketch in Garner and Stratton, *Tudor Architecture*, p. 222.

A few houses of these southern counties (e. g. Middle House, Mayfield, Sussex, *c.* 1575, and Great Tangley Manor in Surrey) follow the half-timber style of Lancashire, Cheshire, Shropshire, and Worcestershire, where elaborate panel-work with cusping was formed by the use of curved and even carved members between the rectangular lines of the framing. During the sixteenth and seventeenth centuries the English forests were thinned,



especially for shipbuilding purposes in the period that Pepys describes in his Diary, and in later work half-timbering tended to be confined to the fronts and backs of houses in Kent, Surrey, and Sussex. The Fire of London marked the end of the epoch when timber-framed houses were traditional and popular, though for long afterwards they were built in certain districts, plastered externally as in East Anglia, or covered with elm weather-boarding as in Middlesex and Hertfordshire.

The Renaissance in Italy does not appear to have led

to any very striking innovations in carpentry, and for the most part simple roof-trusses of low pitch were used, as they had been through the Gothic period in such churches as were not vaulted. The apparently flat roofs that became so popular under the influence of Palladio were usually low-pitched roofs concealed behind a high balustrade, for, though flat 'terrace' roofs were sometimes adopted, they resisted the weather badly even in the comparatively mild climate of Italy. But at the same period various curved roofs were erected built up of short lengths of timber overlapping and bound together. Choisy asserts that such trusses occur in several places and at varying dates, in such a way that they cannot have been copied from one another, and he does not think it likely that Philibert de l'Orme can have copied from the best-known example at Padua this type of roof that now bears his name, still less that the Paduans can have suspected 'that their system belonged to the oldest traditions of India'.

A feature of Italian Renaissance design is the bold projection of the eaves. Fig. 127A shows how this striking effect was obtained by continuing the rafter-ends beyond the wall-face in the form of shaped brackets, a second bracket being added to give additional strength. This example is taken from Brunelleschi's Pazzi Chapel in Florence, and it will be noticed that a string-course takes the place of a cornice, which under so deep an eaves would have little value; but in later work cornices were used.

Ceilings in Italy were richly coffered, and Fig. 127B shows the construction of the famous coffered ceiling of St. Maria Maggiore at Rome. Carpentry played its part in Brunelleschi's dome at Florence (see Fig. 2 in

Jackson's *Renaissance of Roman Architecture: Italy*), but the prime motive for that great constructional adventure was the desire to avoid the use of heavy timber centering.

In France steep-pitched roofs continued to be popular in Renaissance times, and dormer-windows were characteristic of the Renaissance in that country. The introduction of a type of roof with slopes outside and a

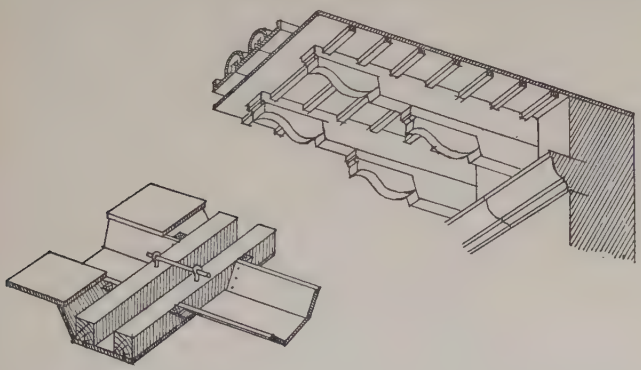


Fig. 127B. Coffered ceiling at S. Maria Maggiore, Rome

Fig. 127A. Eaves brackets from the Pazzi Chapel, Florence

curved effect within is usually attributed, as has just been mentioned, to Philibert de l'Orme, who published in 1561 a manual of carpentry entitled *Nouvelles Inventions de bien bastir et à petitz frais*, in which he shows how to build up ribs for curved roofs, domes, and arches, out of short lengths of timber, instead of cutting them out of the solid. But we have seen that this discovery was made concurrently—if, indeed, it was not anticipated—by Italian craftsmen; and in like manner the 'mansard' roof that appears under that name in

text-books to this day was not in fact invented by François Mansart (1598–1666), still less by his even more famous nephew Jules Hardouin Mansart, but had at any rate been used by Lescot long before. It has always been a question among architectural critics whether the mansard type, combining a steep slope with a low one, is aesthetically satisfactory. The French appear to have thought it so, but at all events it provides a story in the roof more efficiently than any other form does, and for that reason is likely to continue in favour. In the later Renaissance, Italian ideas of design led to a more general use of low-pitched roofs with simple queen-post trusses and purlins, but they have never seemed quite at home in France, where a prominent and generally picturesque roof has always been the traditional type.[1]

The influence of the Renaissance made itself felt very gradually on English carpentry, where tradition was only smothered by degrees. Thus curved braces and brackets, such as have already been described, in connexion with half-timber construction, were used right into the seventeenth century, and open roofs of late date closely adhered to medieval forms. But the genius of Wren showed itself in carpentry as in everything else, and the boldness of his structural design in the dome of St. Paul's is matched also in his City churches and smaller buildings. For instance, recent investigations in the Library at Trinity College, Cambridge,[2] have revealed elaborate trussing and bolting of the heavy

[1] For carpentry of the Renaissance in France and Italy, see Choisy, *Histoire* ii, pp. 618–19, 637, 705, 715–17, 741–2.

[2] See article by H. M. Fletcher in the *R. I. B. A. Journal*, vol. xxx, pp. 388–91 (28 April 1923).

oak floor timbers in order to resist the tendency to deflection set up by the weight of the rows of tall book-cases above. Wren's remarkable success in architecture was certainly due in part to the reputation that he made by applying his scientific knowledge to problems of architectural construction. Certainly neither his draughtmanship nor his knowledge of the Orders made him famous, and this fact may be commended to those aspirants of to-day who find mathematics and building science the chief obstacle in their curriculum to the full development of their genius for 'self-expression'.

Some light on the practice of carpentry in Wren's time is afforded by a chapter in Moxon's *Mechanick Exercises*, a book already mentioned in these pages. In the first place, it appears that carpentry then included much work that nowadays is classed as joinery, viz. doors, windows, flooring, and staircases. The joiner, up to the seventeenth century, had been rather what we should call a cabinet-maker or upholsterer, but about this time, with the increasing standard of domestic comfort, we find carpenters and joiners beginning to quarrel about their respective functions. (The wages of the former, by the way, seem to have averaged about 6*d*. a day during Tudor times, though a master-carpenter would receive a trifle more.) 'Necessity', says Moxon, 'did doubtless compel our Fore-fathers in the beginning to use the conveniency of the first, rather than the extravagancy of the last.'

The tools that he describes in his chapter on carpentry, in addition to those previously dealt with under the head of 'Joinery', include the axe, auger, various forms of chisels, draw-knife (a sort of spokeshave), level, hammer,

'commander' (heavy mallet), 'crow' (crow-bar), and 10 ft. rod. He contrives to get a little fun out of 'The Hammer and its Use':

'This Tool was forgot to be described in *Joinery*, though they use *Hammers* too, and therefore I bring it in here. Its chief Use is for driving Nails into Work, and drawing Nails out of Work.'

'There is required a pretty skill in driving a Nail; for if (when you set the point of a Nail) you be not curious in observing to strike the flat face of the *Hammer* perpendicularly down upon the perpendicular of the Shank, the Nail (unless it have good entrance) will start aside, or bow, or break; and then you will be forced to draw it out again with the *Claw* of the *Hammer*. Therefore you may see a reason when you buy a *Hammer*, to chuse one with a true flat *Face*.'

'A little trick is sometimes used among some (that would be thought cunning Carpenters) privately to touch the Head of the Nail with a little Ear-wax, and then lay a Wager with a Stranger to the Trick, that he shall not drive that Nail up to the Head with so many blows. The stranger thinks he shall assuredly win, but does assuredly lose; for the *Hammer* no sooner touches the Head of the Nail, but instead of entring the Wood it flies away, notwithstanding his utmost care in striking it down-right.'

For the rest, the tools that he describes closely resemble those in use at the present day.

He then proceeds to explain the construction of a timber-framed house from foundation to roof. The description is straightforward and artless, chiefly interesting for his references to the sizes of timber to be used. He takes for the purpose of illustration a typical shop 25 by 40 ft., with a scullery and small yard behind. The sill-piece (resting on a brick foundation)

is 8 in. by 6 in., the angles tenoned together and secured by 1½ in. oak pins which are tapered. On this rise angle-posts also 8 in. by 6 in. The various bressummers and girders are of similar scantlings, the floor-joists are 7 in. by 3 in. with an 8 ft. bearing, and the trimmers are 7 in. by 5 in. Further on we read that in good work no ' Joyces ' are of greater bearing than 10 ft., nor more than 10 in. apart. Moreover, it is clearly stated that in this particular building every joist is tenoned at each end into the plates and girders, and that all ' Tennants ' and ' Mortesses ' are secured with wooden pins. He has a good deal to say about the size that a tenon should be, and next quotes :

' The Scheme of Scantlins of Timber at several Bearings for *Summers*, *Girders*, *Joysts*, *Rafters*, &c., as they are set down in the Act of Parlia. for the Rebuilding the City of *London*, after the late dreadful Fire : Which Scantlins were well consulted by able Workmen before they were reduced into an Act.'

The regulations vary according to the class of house in question, there being three grades (as in the rules for brickwork quoted in Chapter II in this book), and the scantlings throughout are much heavier than we use nowadays, as might be expected. It is interesting to note that the principal rafters of roofs always tapered from plate to ridge, a practice now quite abandoned. On his Plate 11 he gives a section of the shop with the king-post roof and the trussed partitions exposed. He also provides an extensive glossary of terms used in carpentry, and gives, in italics, a list of ' General rules ' from which the following are taken :

' That no Timber be laid within twelve Inches of the

fore side of the Chimney Jambs: And that all Joysts on the back of any Chimney be laid with a trimmer at six Inches distance from the Back.'

'That no Joysts or Rafters be laid at greater distances from one to the other, than twelve Inches; and no Quarters at greater distance than fourteen Inches.'

'That no Timber be laid within the Tunnel of any Chimney, upon Penalty to the Workman for every Default ten Shillings, and ten Shillings every Week it continues un-reformed.'

'That no Joysts bear at longer length than ten Foot; and no single Rafters at more in length than nine Foot.'

'That all Roofs, Window-frames, and Celler-floors be made of Oak.'

'No Summers or Girders to lie over the Head of Doors and Windows.'

'No Summer or Girder to lie less than ten Inches into the Wall, no Joysts than eight Inches, and to be laid in Lome.'

Moxon was followed by other writers of manuals on architecture and building construction, among them Batty Langley, from whose books quotation has already been made in Chapter II. His *A Sure Guide for Builders* (1729) gives the same scantlings as Moxon does, and mentions tapered principals. *The Builder's Compleat Assistant* is far more concerned with the classical 'Orders' than with building, but also gives a selection of designs for roof-trusses—some of which are unusual—and details of trussed partitions, floors, dragon-ties, domes, spires, and timber bridges. *The Builder's Jewel: or, the Youth's instructor and Workman's remembrancer* (1757) is, even more than the last, an architect's copy-book of the Orders; such constructional plates as it does include resemble those in the last-named work.

Looking through these old books one cannot fail to be struck by the absence of elementary constructional details to a large scale. Thus, each contains many suggestions for the outline of a roof-truss, but no details of its various joints, or indeed of any ordinary joints in carpentry. All the A B C of building seems to have been taken for granted in the 'Youth' or 'Workman' who was the reader; those details he was evidently expected to have mastered already.

At a rather later date appears Mr. William Pain, 'Architect and Joiner', who in 1774 published *The Practical Builder, or Workman's General Assistant*, and directed his labours, as his preface states, 'Plainly and faithfully to answer the Purpose of the manual Artificer'. Yet almost the whole of the book consists either of plates of 'Gentlemen's Houses', or of details of the Orders, construction being relegated to a few plates involving the intricacies of geometrical setting-out, and a few more of trussed girders and roofs. But so far as practical building interests him at all, it is limited to carpentry on a large scale. Thus he illustrates a 'Plan of an M Roof, with Hip and Valley in Ledgment', a truss with curved braces of Gothic type, a curb roof of mansard form, and so on. His *Practical House Carpenter: or, Youth's Instructor* is similar in many respects to the last, only 15 plates out of 116 being in the least practical. But in the text appears a set of tables for timber scantlings, from which I have prepared the following extract for comparison with modern practice. All the figures are for fir, though he also give scantlings for oak.

Girders	.	.	16 ft.	bearing	.	.	. 11 × 13 ins.
,,	.	.	24 ,,	,,	.	.	. 14 × 16 ,,
Joists	.	.	6 ,,	,,	.	.	. 6 × 3 ,,
,,	.	.	12 ,,	,,	.	.	. 12 × 3 ,,
Principal rafters			15 ,,	length	8	tapering to	7 × 6 ,,
,,	,,		30 ,,	,,	10	,, ,,	9 × 8 ,,
Common	,,		8 ,,	bearing	.	.	. 5 × 3 ,,
,,	,,		12 ,,	,,	.	.	. 9 × 3 ,,
Purlins	.	.	8 ,,	,,	.	.	. 8 × 6 ,,
,,	.	.	12 ,,	,,	.	.	. 10 × 8 ,,

He also prints as an appendix a very long list of builders' prices then prevailing, of great interest, from which it appears that a carpenter's wages were 5*d.* an hour or 4*s.* a day.

From that date onwards there was a steady flow of books on carpentry which show us the progress of the craft, but serve still more to remind us how little anything in carpentry has changed. The carpenter's tools, his materials, his joints, and his whole theory of work, have altered surprisingly little for centuries. We now use methods of framing woodwork that were in vogue three thousand years ago in Egypt. There is hardly anything in a modern book on carpentry that is less than a century old, and a hundred years hence there is not likely to be much further development. The reason for this probably is that the craft of carpentry has grown up slowly and naturally, limited by the nature of the timber that it uses and has always used. When architects have been handling reinforced concrete for three thousand years or so, they will probably feel as much at home with it as a present-day cabinet-maker can feel among the Egyptian furniture to be described in the next chapter.

VI

JOINERY

To a modern architect there is a clear distinction between the work of the carpenter and that of the joiner. The former includes the framing of roofs, floors, and partitions; the latter comprises the framing of the lighter woodwork of a building—doors, wall-panelling, windows, and staircases, as well as the laying of floor-boards and the making of cupboards and shelves. Perhaps the only works in wood that might be classed under either head are the open floors or ceilings with moulded beams that were largely used in Tudor times. But long ago, as was noted in the last chapter, the joiner seems to have been chiefly a maker of portable furniture, whereas the carpenter was responsible for all the woodwork of a building. The explanation may well be that there was very little of what we now call 'joinery' in a medieval house. In the time of Wren, when carpenters and joiners were beginning to dispute about their respective functions, Moxon wrote:

'Joynery is an Art Manual, whereby several Pieces of Wood are so fitted and joined together by straight Lines, Squares, Miters, or any Bevel, that they shall seem one intire Piece.'[1]

Another craftsman of medieval days was the 'Inblower', who seems to have been a joiner of sorts.

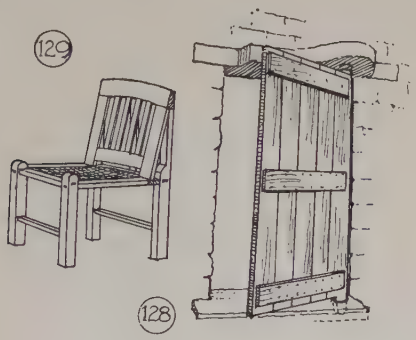
This chapter is mainly concerned with the develop-

[1] Moxon, *Mechanick Exercises*.

ment of doors, wall-panelling, and the simpler processes of joinery, though something will be said of staircases. Windows will be treated in Chapter XI, under the head of 'Glazing'.

Thanks to the wonderful climate of the Nile valley, we know more of the joinery of the ancient Egyptians than of any subsequent period till we reach Tudor times in England. Moreover, the Egyptian galleries of the British Museum provide us with an admirable series of examples. From these we learn that the Egyptians excelled in the craft, as in so many others, and attained a degree of skill that was certainly not surpassed in this country till the fourteenth or even the fifteenth century of our era. It has already been noted in Chapter V that suitable timber in Egypt was scarce, and that foreign woods, especially cedar, were imported. From very early times dovetailing was practised, as may be seen in some of the oldest coffins in the British Museum, pins being used to strengthen the joints. Halving, bevelled halving, several forms of mitreing, mortising and tenoning, and housing were also understood. Statues were made of wood as well as of more enduring materials, and if of large size were formed of several pieces pegged together. Usually the trunk, head, and legs were carved out of one block, the arms being attached. One of the most wonderful works in the whole world is the wooden statue of the 'Sheykh el-beled' (Head-man of the Village), in the Cairo Museum, nearly five thousand years old. But of architectural woodwork not much survives. Thus we have no remains of the huge wooden doors or gates that must once have hung at the entrances to the temples. But in the British

Museum (No. 566, 5th Egyptian Room) is a complete door of a tomb of the eighteenth–twentieth dynasties. It is about 8 ft. by 4 ft., of a dark-coloured wood decorated with a painted panel. It consists of five boards about $2\frac{1}{2}$ in. thick with three battens behind them. Fig. 128 shows how it must have been hung. The board on the right is continued downwards in the form of a pointed foot or 'ear'. This revolves in a socket in the stone threshold. One such socket is preserved in



the British Museum. At the top is either a similar 'ear' or a circular pin, let into a projection of the lintel, made for the purpose. This method is easily understood by examining the little models of houses in the 4th Egyptian Room, and it will be referred to again in this chapter. Ingenious wooden latches were fitted to these doors.

Figs. 129 and 130 illustrate a cane-seated chair in the British Museum, and show the skilful system of framing used. Professor Petrie says that :

'Wood was carefully trained for ten or twenty years of growth to form the right-angle pieces needed for

joints. Even a three-legged stool, all in one piece, was made by training three branches in the right directions, and then cutting the seat out of the trunk.' [1]

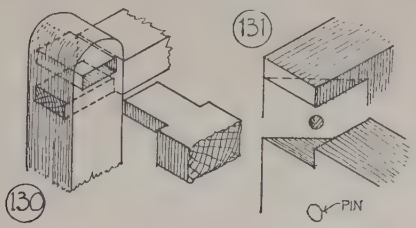
Fig. 131 represents a common form of joint. There is a great difference in workmanship between the oldest coffins (of wood several inches thick), the shoddy coffins of 1 in. boarding made under the Ptolemies and the Romans, and the elaborate stools, chairs, and thrones exhibited in the 4th Egyptian Room, where also examples of ivory inlay may be seen. Much of the joinery of the ancient Egyptians was originally coloured and gilded. But it was not all above reproach. Again quoting Professor Petrie :

'There was, however, the sham of cheap imitations. Where a tenon of a crossbar was supposed to go through a chair leg it was only short, and a piece of inlay was let in where it should come through. Veneers of ebony and other foreign woods were glued on. Patterns were done in white paint instead of inlaid with ivory. Paint grained to imitate valuable woods was as common as in Victorian houses ; painted wood even did duty for valuable stone vases ; grained wood patterning, showing all the knots and waviness, was excellently painted as early as the IIIrd and IVth dynasties.' [2]

Hardly a trace remains of wood construction under the various civilizations that flourished in Mesopotamia and Persia in ancient times. What little we know is based on the evidence of bas-reliefs and inscriptions. The British Museum possesses examples of gate-sockets and door-sockets in marble, basalt, and stone, as well as some bronze pivots, and a tablet giving a list of the

[1] Petrie, *Social Life in Egypt*, pp. 144–5.
[2] *Ibid.*, p. 146.

various woods used. Furniture was often made of cedar brought from Lebanon and elsewhere, and this woodwork was so valuable that the lessees of houses often removed the doors at the expiry of a lease, regarding them as 'tenant's fixtures'. Mortising, tenoning, and dovetailing were employed, as in Egypt, and the standard of craftsmanship was high. Ebony, Indian walnut, teak, perhaps rosewood, and other timbers were imported from Europe and India. Ebony and ivory were used for inlaying furniture. But in regard to architectural



woodwork the most valuable evidence is supplied by certain passages of the Old Testament. Thus, in Jeremiah xxii. 14, we read: '. . . I will build me a wide house . . . and it is cieled with cedar and painted with vermilion.' Other passages (1 Kings vi. 15 and vii. 3) state that Solomon panelled the walls of his temple with boards of cedar of Lebanon, that the beams of the ceilings were of the same material, and that the floorboards were of fir. Zephaniah (ii. 14) mentions the cedar in the buildings of Nineveh.[1]

In pre-Hellenic Greece and in Crete joinery was certainly used, but we know little about it. A complete carpenter's kit was found in the ruins of the town of

[1] On joinery at Nineveh, see Layard, *Nineveh*, pp. 344, 346.

Gournia (burned and destroyed in 1500 B. C.), including long and short saws, chisels, awls, nails, and files, all very much like modern tools.[1] Double doors were used in the Palace at Knossos. Even Hellenic Greece provides little more evidence as to joinery methods. The doors of the temples were sometimes of marble (as at the Erechtheum), more often of bronze—though this may mean plated with bronze,—but no woodwork remains. We may assume that wooden furniture was used to some extent, that it was inlaid and otherwise decorated, and that it was designed with taste and skilfully constructed.

As to Roman joinery we have a little more information, but here again actual examples hardly exist. Folding doors were often used, sometimes of bronze or of wood plated with bronze. They were hung either on bronze strap hinges (of which there is a specimen in the British Museum) or on *cardines* (pegs or 'ears'), as described above in the case of Egyptian doors, turning in sockets. These have been found in Roman stations in England. The front door (*janua*) was generally decorated with bronze mounts. Vitruvius [2] gives rules for the proportion of doors in temples and dwelling-houses, based on the size of the opening. Thus each hinge-style of a pair of folding-doors should be one-twelfth of the width of the doorway. The height of the lock-rail should be three-fifths of the height of the opening. Locks were understood, and in the British Museum is a restored model showing the mechanism (Fig. 151a). Inner rooms frequently had curtains instead

[1] Hawes, *Crete, the Forerunner of Greece*, p. 37.
[2] Vitruvius, IV. vi. 5, and VI. iii. 6.

of doors. Door-frames were sometimes carved and inlaid. Ceilings of open timber beams were often used, occasionally painted and gilded. In large houses the structural timbers were lined with boards and panelled into coffering (*lacunae*). A great variety of timber was used for ornamental joinery and furniture. Pine was employed for doors, panels, and glued work generally; elm for door-frames and the thresholds containing the sockets; cedar, especially that from Crete, Africa, and Syria, for many purposes; bird's-eye maple and other richly figured woods for furniture. Veneering and marquetry with these woods and with tortoise-shell and ivory were also practised, and even 'graining', which is a sad blow to those who believe in the invariable truthfulness of the old builders; for cheap wood was actually grained to represent costlier kinds![1]

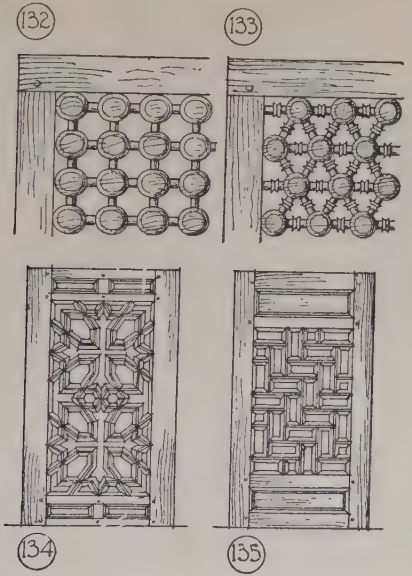
Of Byzantine joinery so little is recorded that we may pass on to the Saracenic work of the Middle Ages in Cairo. This is of far more interest and value to us than might at first be supposed, as it affords an excellent illustration of the adaptability of art to practical considerations, in this case both climatic and social. Saracenic art, moreover, had a great influence on later work in England, and the medieval craftsmen of Cairo were possessed of an amazing patience, characteristic of the Oriental worker, so that no joinery was too intricate or minute for their skilful hands. In the West Hall of the Victoria and Albert Museum is preserved a magnificent collection of this Cairo woodwork, though unfortunately many of the smaller pieces are difficult to see owing to their position.

[1] See J. H. Pollen, *Furniture and Woodwork*, vol. i, p. 48.

The hot climate of Egypt directly influenced the interior equipment of the house, for the minimum of furniture was used. But in the design of panelling, whether of doors, walls, or cupboard-fronts, climate again played a part. The tendency of wood to shrink in the powerful sun led to the employment of very small panels, and to the subdivision of a flat wooden surface into the maximum number of pieces. Figs. 134 and 135 illustrate two small panelled doors, probably of cupboards, in the South Kensington Museum. Each of them is about 3 ft. 4 in. by 1 ft. 8 in., and $1\frac{1}{4}$ in. to $1\frac{1}{2}$ in. thick. The date is uncertain, for tradition died very slowly in Cairo, and it is often difficult to distinguish work of the sixteenth century from that of the eighteenth. But these doors are typical; they show the similarity of late medieval panelling in Cairo to that of our Elizabethan period, and especially the minute character of the panels; thus, fielded or bevelled panels are often as small as $2\frac{1}{2}$ in. by $\frac{3}{4}$ in. and the elaborately moulded framing between is less than $\frac{3}{4}$ in. wide. These examples also show the love of the Saracens for complicated geometrical patterns, to which they were susceptible not only by reason of their innate fondness for geometry, but also because of the Islamic veto on all natural forms. At South Kensington one may also study the marvellous inlaid woodwork of the pulpits and other furniture of the mosques, the rich carving of woodwork, and a wooden ceiling.

In the West Hall, too, are some wonderful bay-windows of *mashrabiyyah* or lattice-work, and in the apse a number of smaller specimens (Figs. 132 and 133). In Egypt, cool fresh air is very desirable in a house,

whereas sunshine is a thing to be avoided. Enough light for ordinary purposes comes through the chinks of a shutter. This lattice-work was therefore evolved to serve the triple object of (*a*) admitting diffused light and fresh air; (*b*) furnishing a place in which jars of water



could be kept cool; and (*c*) providing the fair inmates of the house with a view of the street without exposing them to the rude gaze of passers-by.

The third object was the most important, and to achieve it the squares of lattice-work are normally $1\frac{1}{4}$ in. to $1\frac{3}{4}$ in. apart, this being a convenient spacing to enable those within the house to look out. The construction of these turned lattices is very ingenious. The designs

vary greatly, and sometimes the little reels or 'bobbins' are arranged to form inscriptions or emblems. Similar work is found in the mosques. In Rosetta and Damietta a completely different form of lattice was used.[1]

Romanesque or 'Norman' joinery in England is of little importance. A few examples of doors remain (e. g. at Castor and Sempringham, the latter with contemporary ironwork). Such doors were generally of oak, though that at Sempringham is of deal, and were formed of a thick plank the full width of the door, without any joints, and depending for ornament on the rich scroll-work hinges (see Chapter VII). The doors of houses were often small, and were usually loose pieces of wood without hinges. Most Norman woodwork in churches was painted (e. g. the original ceilings of Canterbury and Peterborough Cathedrals). The Norman castle contained very little joinery or wood furniture: possibly only a bench or seat for the owner's personal use, and a chest or two.

With the thirteenth century came the introduction of wood panelling. This is said to be due to Henry III, who ordered a chamber at Windsor to be panelled with Norway pine, specially imported.[1] (The boards were coloured and only two clear days were allowed for fixing and completion.) It was, however, a long time before panelling came into general use, nor was it used in the construction of doors, but it was employed for the framing of chests and coffers. Oak was the favourite timber. Beech and elm were also used, and occasionally

[1] On Saracenic joinery, see M. S. Briggs, *Muhammadan Architecture in Egypt and Palestine*, pp. 209–19; and E. Lane, *Manners and Customs of the Modern Egyptians*, Introduction.

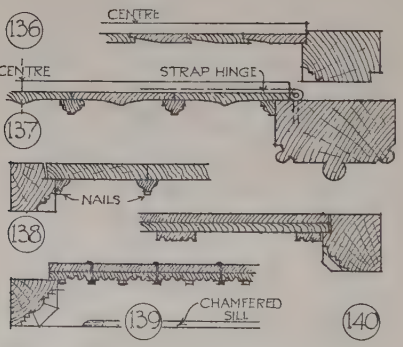
pine and chestnut. Joinery was often decorated in colour. Mouldings and detail generally followed in miniature those of contemporary masonry, but were simpler and more delicate. Thus, an early thirteenth-century example—the great west door at Peterborough—has dog-tooth ornament inside. A later instance is the door of York Chapter-house, in deal.

In the fourteenth century the design of wooden doors advanced. A single door, or a pair of doors, in the arched doorway of a church, were made to resemble a traceried window in stone. The ' tracery ' was applied to the heavy boarding of the door, and the ' mullions ' were represented by vertical strips of wood similarly applied. This applied work was thin, and in many cases has perished before the more massive structure of the door proper, usually exposing a vertical joint in the outer layer of boarding behind each ' mullion '. The inner layer of boarding generally had horizontal joints, thus forming a continuous series of battens—a modified form of the ' ledged ' door such as the ancient Egyptians used, and such as has been employed since the days of Wren for the less important doors of dwelling-houses. The boards were not always flush, but were sometimes shaped as in Fig. 137. The moulded strips were usually 2 in. to 3 in. wide and of $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. projection. Much of the effect depended on the arrangement of the wrought-iron nails with roughly square heads with which the door was studded in vertical rows. These nails were driven through the moulded vertical strips, the iron strap-hinges, the vertical outer boarding, and the horizontal inner boarding, and then the points were clenched

[1] J. H. Pollen, *op. cit.*, p. 60.

on the inside and left exposed. This type of door, illustrated in Figs. 136, 137, 138, 139, and 140, was used up to the time when panelled doors became general, early in the sixteenth century.

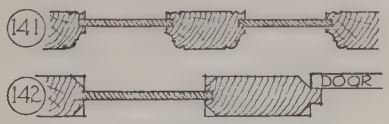
During the same period took place the development of wall-panelling. The earliest examples show that panelling was at first only a form of half-timber construction used internally. The framing was of massive posts and rails about 4 in. by 3 in., the former fixed



about 18 in. to 2 ft. apart, with a rail at 3 ft., 4 ft., or 5 ft. above the floor level according to the height of the room (Figs. 141 and 142). The framing was tenoned and pinned, sometimes splayed, but more generally moulded. The panels consisted of boards let into the framing.

This type of framing was progressively reduced in thickness till by the middle of the sixteenth century it was often only 1 in. thick. At the same time the panels were narrowed to the more convenient width of 10 in. to 12 in. and their height reduced to 18 in. or

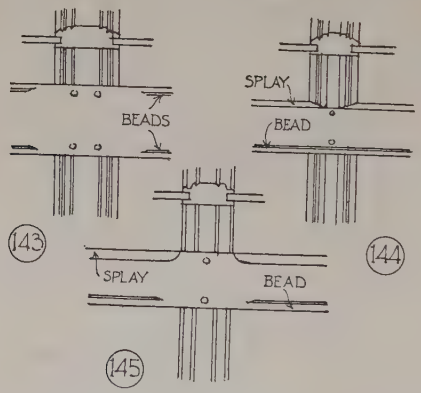
so. These dimensions were maintained until the time of Inigo Jones. Linenfold panelling was introduced, probably from Flanders, in the latter part of the fifteenth century, and continued in use up to the fourteenth century, when it was supplanted by panels carved with Renaissance ornament, and later still by the Elizabethan and Jacobean treatment with applied pilasters, arches, and other features, and with inlay such as one sees in the well-known example from Sizergh Hall. All these later developments may be studied at South Kensington, but they have no special constructional importance.



Tudor panelling was invariably moulded on the solid. At first the mouldings were 'stopped' at their intersection (Fig. 143) owing to the difficulty of making a mitred joint, or else the craftsman's ignorance of it. Then a splay was introduced on the upper edge of the rails, and the moulding scribed to it (Fig. 144), or the splay itself was stopped at the intersection (Fig. 145). Generally the mouldings ran continuously on the vertical members, the rails being splayed above and beaded below. Finally the mitred joint came into common use, but the splay was retained after this, for it saved much labour in dusting, and not till the time of Inigo Jones did this excellent feature give way to what his age probably called 'architectural propriety'. Practically all this panelling is of oak. Throughout Elizabethan and Jacobean times its construction varied little. Oak

pins were used for securing the tenons. The craftsmanship was excellent, the mouldings very delicate, and the framing very light (Fig. 149). Doorways in early panelling were treated as part of the general scheme, and were flush, without architraves or other projecting features.

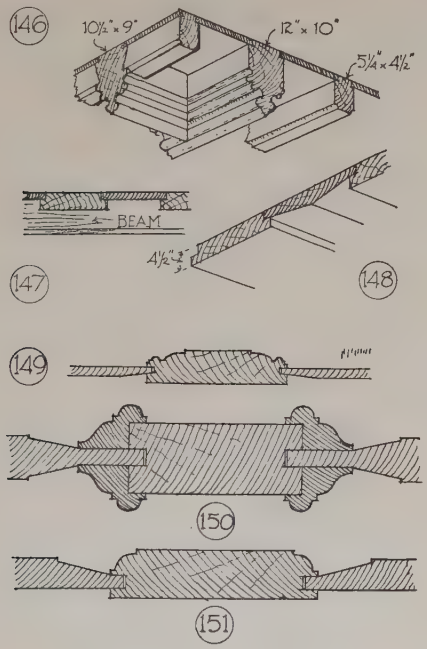
Figs. 146, 147, and 148 show the usual method of floor-construction between *c.* 1450 and *c.* 1650, the



former being an elaborate example from Crowhurst Place, Sussex. Plaster ceilings came into general use after *c.* 1550.

The remarkable change that occurred in the development of panelling from about 1650, when Inigo Jones came into prominence, is easily understood if one studies the fine series of panelled rooms from Clifford's Inn (1686–8), Hatton Garden (*c.* 1730), and Great George Street (1750–60), at the Victoria and Albert Museum, and if one compares them with the earlier examples already described. The first-named is of oak, and has large

raised panels with projecting or 'bolection' mouldings mitred round each. The other two are of pine, plentifully studded with knots, and have large panels, each formed of several boards glued together. Between the



dado-rail in the Great George Street example and the skirting (the latter a feature not found in early panelling) is the dado, formed of three boards. Pins are used in all these instances to secure the tenons. Figs. 150 and 151 illustrate two specimens from Hampton Court, now at South Kensington, showing the same stages of development.

Moxon, in his chapter on 'Joinery' in his book *Mechanick Exercises*, which, as I have already noted, is contemporary with Wren, writes thus '*Of Wainscoting Rooms*':

. . . 'In Wainscoting of Rooms there is, for the most part, but two heights of Pannels used; unless the Room to be Wainscoted be above ten foot high, as some are eleven or twelve Foot high, and then three Heighths of Pannels are used; As I The *Lyning Pannel*, above the *Base*. K The *Large Pannel* above the *Middle Rail*; And L The *Friese Pannel* above the *Friese Rail*.' [Initial letters refer to his plate, not reproduced here.]

'The *Friese Rail* is to have the same breadth the *Margent* of the *Stile* hath; The *Middle Rail* hath commonly two breadths of the *Margent* of the *Stile*, viz. one breadth above the *Sur-base*, and the other below the *Sur-base*. And the *Upper* and *Lower Rails* have also each the same breadth with the *Margent* of the *Stile*.'

. . . 'Sometimes (and especially in low Rooms) there is no *Base* or *Sur-base* used, and then the *Middle Rail* need not be so broad: For the *Middle Rail* need not be above a third part more than the *Margent* of the *Rail*: and the *Lower Rail* you may make of what breadth you see convenient: They are commonly about three Inches and an half, or four Inches broad, yet this is no Rule: For sometimes Workmen make only a flat Plinth serve.'

'You may (if you will) adorn the outer edges of the *Stiles* and *Rails* with a small *Molding*: And you may (if you will) Bevil away the outer edges of the *Pannels*, and leave a Table in the middle of the *Pannel*.'

From this extract it appears that the design of panelling at the end of the seventeenth or beginning of the eighteenth century was largely left to the discretion of the joiner, and also that it followed traditional and

accepted rules. Moxon says nothing about the kind of jointing or the moulding to be used. Those were evidently points on which a skilled craftsman was expected to have the necessary knowledge. The usual door-furniture for large houses of this period included a brass box-lock and escutcheons, mortise-locks not being introduced until the middle of the eighteenth century.

At that period wooden wall-panelling gradually gave way to a very different treatment in stucco, for which the brothers Adam later became famous. As Sir Reginald Blomfield writes:

'The sense of woodwork as woodwork capable of effects peculiar to itself was forgotten,—as with the other crafts of architecture, by the end of the eighteenth century, architects had lost their touch of material.' [1]

The introduction of walnut for portable furniture and of lime for carving hardly comes under the head of 'joinery', but it may be noted at this point that the use of mahogany, except as a veneer and for portable furniture, dates from the middle of the eighteenth century, when it became the fashionable material for doors which were highly polished. A slightly earlier example of its use for this purpose is to be found at Houghton Hall, Norfolk (1722–35).

It must be mentioned that the development of joinery in remote districts seldom kept pace with its advance in the towns, especially during the later periods, and that the curious method of pivoting doors on wooden 'harrs' or ears, used by the ancient Egyptians as

[1] R. Blomfield, *Short History of Renaissance Architecture in England*, p. 248.

described above, persisted in Yorkshire barns and elsewhere, according to Mr. Innocent,[1] as late as the nineteenth century.

The evolution of the staircase has been well described by Mr. Innocent in his *Development of English Building Construction*,[2] so far as the more primitive types are concerned. He points out that in early times ordinary houses were of one story only, and that in 1254, according to an authority quoted, London houses seldom, if ever, exceeded two stories in height, including the basement. It was not, indeed, until the fifteenth century that upper stories became general. Early domestic staircases were of five main types: 'an upright pole with pegs driven through it and projecting, for the hands and feet'; a ladder pure and simple; 'a staircase cut out of a solid balk of oak in a straight flight' . . .; 'a staircase in a straight flight as the last, but each step is cut out of the solid timber', on the same principle that is now employed for solid steps of stone or concrete; and 'the so-called circular steps, in which the newel is a straight, upright tree and the steps are framed into it'.

But none of these varieties constitutes 'joinery', and our story really begins at the point where Mr. Innocent ends, with the introduction of steps formed of separate strings, risers, and treads, framed and glued together. This type, at any rate except in large houses, is characteristic of a date later than 1600. Meanwhile it must be remembered that even the houses of the ancient

[1] C. F. Innocent, *Development of English Building Construction*, pp. 242–4.

[2] *Ibid.*, pp. 168–70.

Egyptians had upper stories, usually approached by staircases of about 27 in. wide (according to Professor Petrie [1]), and that in Imperial Rome, as in Saracenic Cairo, tenement dwellings of many stories are known to have existed; but in all these cases it is unlikely that joinery was used in staircase construction.

In Elizabethan and Jacobean times in England the plan of the staircase was either of the 'dog-legged' or of the 'open-newel' type. The latter form had short flights (with not more than five or six steps in each), and the landings were square. The newels were always stout, and had turned or shaped tops and pendants. The heavy oak handrail was, in section, deeper than its width. Sometimes double newels were used in dog-legged staircases (in order to avoid cutting the strings), this being excellent craftsmanship. In other cases we find continuous newels, running up from floor to floor. The balustrade was formed either of pierced and fretted pilasters, each made of one stout strip of wood, or of sturdy turned and decorated balusters, $2\frac{1}{2}$ in. to 3 in. in diameter. In late Jacobean work a continuous balustrade is often found, formed of one large piece of wood filling the whole space from the top of the outer string to the underside of the handrail. (Cromwell House, Highgate, is a fine example of this type.) Under the skilful hand of Grinling Gibbons this enormous panel was pierced and carved into the semblance of flowing foliage.

Inigo Jones developed the balustrade in accordance with Renaissance ideas, and took for his model the heavy stone or marble balustrades used to crown the façades of

[1] Petrie, *Social Life in Egypt*, pp. 172–3.

lofty palaces in Italy. Beautiful as are his staircases at Coleshill and Ashburnham House, they are formed of masonry elements translated into terms of wood, and thus break the continuous tradition of English craftsmanship. The newels were at the same time replaced by heavy panelled pilasters, round which the mouldings of the broad handrail were returned to form capitals. Thus the whole effect of timber-framed construction was lost.

Roughly coeval with these were the light twisted wooden balusters (usually three different turned and twisted balusters to each step) that lasted into Georgian times. Other types characteristic of the late seventeenth and the eighteenth centuries were merely turned, often of admirable proportions, while during this period the cut spandrel string and the stepped string made their appearance.

In the last quarter of the seventeenth century iron scrollwork was introduced to take the place of wooden balustrading, an early example being the King's Staircase at Hampton Court, by Jean Tijou. (The subject of decorative ironwork is treated in Chapter VII.) In the later eighteenth century, when the 'geometrical' staircase (as illustrated in every modern book on building-construction) became usual, the balusters were commonly of iron, sometimes with lead enrichment, and only the mahogany handrail was of wood. The modern wooden staircase, whatever its form, only differs in construction from its historical prototypes in the lightness of the joinery used.¶

Fig. 151A illustrates the use of wooden locks in the past. '1' is a form common in the medieval buildings

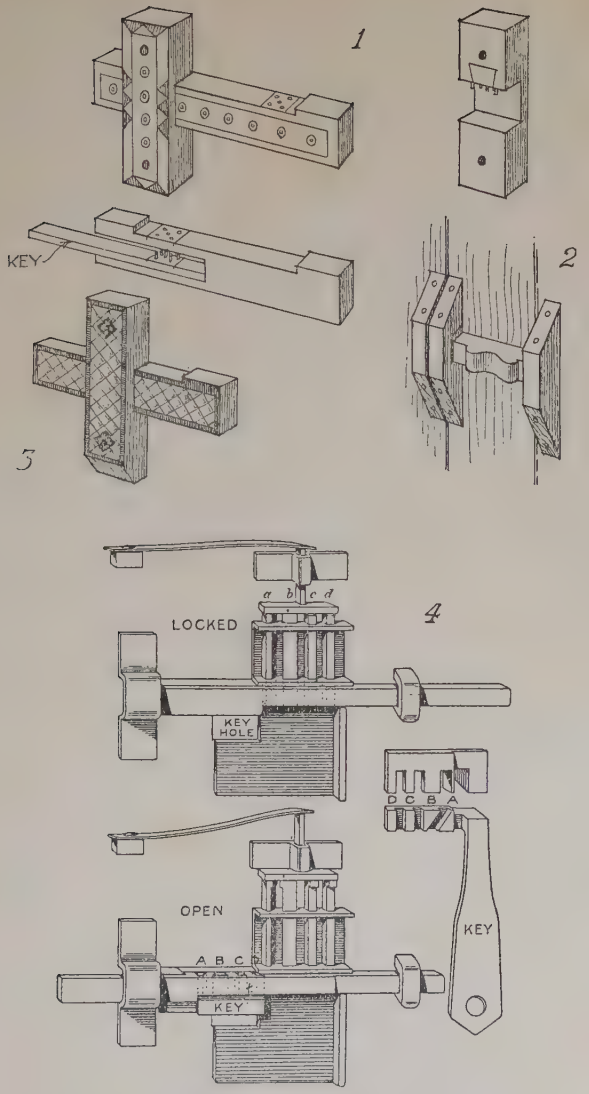


Fig. 151A. Latches and Lock

(1) Saracenic, from Cairo; (2) Saracenic, from Damascus; (3) English, from Yorkshire; (4) Roman, from the British Museum, restored.

of Cairo, and is taken from Edward Lane's *Manners and Customs of the Modern Egyptians*.[1] As he says:

'No. 1 in this sketch is a front view of the lock with the bolt drawn back; Nos. 2, 3, and 4 are back views of the separate parts, and the key. A number of small iron pins (four, five, or more,) drop into corresponding holes in the sliding bolt, as soon as the latter is pushed into the hole or staple of the door-post. The key, also, has small pins, made to correspond with the holes, into which they are introduced to open the lock: the former pins being thus pushed up, the bolt may be drawn back. The wooden lock of a street-door is commonly about fourteen inches long: those of the doors of apartments, cupboards, &c., are about seven, or eight, or nine inches. The locks of the gates of quarters, public buildings, &c., are of the same kind, and mostly two feet, or even more, in length. It is not difficult to pick this kind of lock.'

'2' is from a sketch of my own, made in the Khan Asad Pasha at Damascus.[2] This example resembles the last-named in mechanism, and is inlaid with mother-of-pearl, a favourite material among craftsmen of that city. '3' is adapted from Innocent's *Development of English Building Construction*. '4', included for purposes of comparison, is an ingenious restoration from the *Guide to the Antiquities of Roman Britain in the British Museum*, but is of metal. It illustrates a 'tumbler-lock with toothed key, the latter being inserted to lift the vertical pins so as to release and slide the bolt'.[3]

Something has been said, both in this chapter and in

[1] Lane, *op. cit.*, pp. 20–1.

[2] For an illustration of the door on which this is fixed, see my *Muhammadan Architecture, &c.*, Fig. 206.

[3] *Guide to the Antiquities of Roman Britain, &c.*, p. 44.

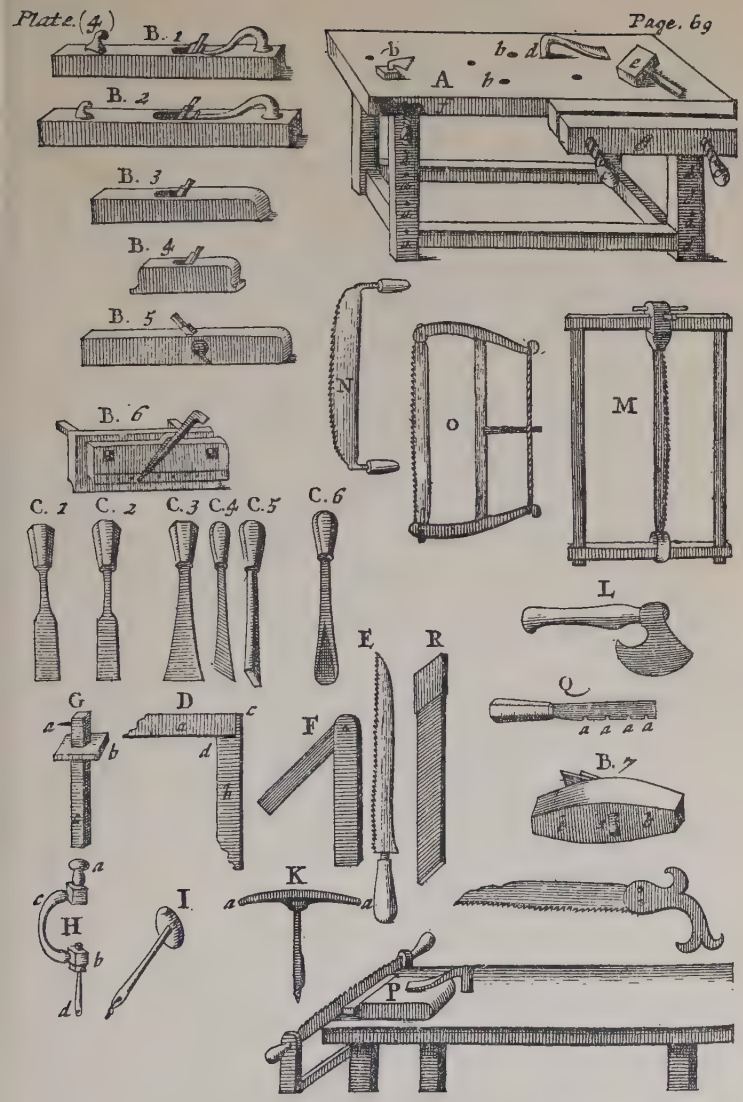


Fig. 151B. Joiners' Tools (from Moxon's *Mechanick Exercises*, 1678.)

the preceding one, of the tools used by carpenters and joiners in the past. The greater part of the sections devoted to joinery in Moxon's *Mechanick Exercises* is concerned with the description of such tools and their use in his day. Fig. 151B reproduces his Plate 4, and is included here primarily to show how slight a change has taken place in their form during more than two centuries. (In the following description I use Moxon's own spelling.)

'A' is a bench, 'b' a bench-hook or stop, 'c' a bench-screw, 'd' the hold-fast, '*bbb*' round holes for the hold-fast, and 'e' a mallet; 'B 1' a Fore plain, used for preliminary smoothing of rough work, and provided with a slightly convex iron, the sharpening and setting of which is described in great detail; 'B 2' a Joynter; 'B 3' a Strike-block; 'B 4' a Smoothing-Plane; 'B 5' a Rabbet-Plane; 'B 6' a Plow, used for cutting grooves on the edge of a board and with an iron usually about 1 in. broad; next follows a description of various forms of Molding-Planes, not illustrated, which are made with irons of many sections (including the Round, the Hollow, the Ogee, and the Snipe's Bill) from $\frac{1}{2}$ in. to $1\frac{1}{2}$ ins.; and 'B 7' is apparently included to explain his instructions for setting a plane.

'C 1' to 'C 6' represent Chissels of several sorts, 'C 1' and 'C 3' being Formers; 'C 2' is a Paring-Chissel; 'C 4' a Skew-Former; 'C 5' a Mortess-Chissel; and 'C 6' a Gouge. 'D' is a Square, of which the use is fully explained; 'E' is said to be a Miter Square, (but here there is obviously some confusion); 'F' is a Bevil, with its Tongue movable upon a Center; 'G' a Gage; 'H' a Piercer, with 'a' the Head, 'b' the Pad, 'c' the

Stock, and 'd' the Bitt; 'I' a Gimblet; 'K' an Augre; 'L' a Hatchet; 'M' a Pit-Saw; 'N' a Whip-Saw for use by two men; and 'O' a Saw-wrest, (this obviously should read 'Q'), for setting saw-teeth.

He is confused about the Hand-Saw, the Frame or Bow-Saw, the Tennant-Saw, and the Compass-Saw, but three of these appear to be illustrated in his Figs. 'E', 'O', and the example in the bottom right-hand corner. He also mentions the Rule, Compass, and Glew-pot; describes the making of a mortise and tenon joint; and discusses the advantages of steel over iron for saw-blades.

This short chapter on joinery serves to emphasize many points which constantly recur in studying the building crafts of bygone days: that considerations of climate and social requirements have always influenced 'artistic' design; that the limitations of materials were recognized as long as tradition maintained a free course; that the introduction of the 'copybook' frequently caused common sense to be forgotten; that shams and subterfuges are sometimes found in unexpected places; and that tools and methods have altered little for centuries in crafts where no change of type has become necessary.

VII

IRONWORK

THERE was a time, not so very many years ago, when the use of ironwork in the construction of buildings was the subject of violent writing on the part of Ruskin and his school. Even at the present day, when the general adoption of steel in some form for all buildings of any magnitude and indeed for some part of almost every building makes these heated attacks seem ridiculous to us of a younger generation, the spell of Ruskin is not altogether broken. Perhaps it is due to his influence, perhaps to the amazing conservatism of architects as a class, that even now we do not handle steelwork in our designs with the same freedom with which we employ older materials. For the latter we have the example of the Pharaohs and a long line of their successors to give us confidence!

Ruskin's attitude towards ironwork, railways, and modern innovations in general was perfectly clear and perfectly unreasonable. But it must be remembered that he preached when the Gothic Revival was at its height, when the cast-iron columns of railway-stations were being moulded into coarse caricatures of the graceful Gothic shafts and foliaged capitals that he loved. Had he lived in our day, when steelwork is usually treated as an anatomical part of the building and is free from the meaningless ornament of mid-Victorianism, he would probably have found little fault with the trend

of modern practice in this direction. The defect of Ruskin's position lay in holding that a utilitarian building, such as a railway-station, should be made definitely hideous because it represented the evil idea of industrialism. It was in such a building that he objected to all attempts to make ironwork beautiful, and, considering what those attempts were, one can easily understand and even accept his point of view. He rightly contended that the type of ornament adopted in his day for cast iron was closely copied from medieval models of stone, wood, or brick; that obviously the same proportions could not be applied to cast iron, with its different factor of strength; and that '. . . no ornaments are so cold, clumsy, and vulgar, so essentially incapable of a fine line or shadow, as those of cast iron'.[1]

All this is concerned with ornament, and Ruskin was far too apt to regard ornament as synonymous with architecture. It is part of his legacy to posterity that the general public and their friends the jerry-builders regard the architect as the man who applies the ornament rather than as the master-builder. Ruskin holds that metal may be used as a means of securing woodwork and masonry, in the form of rivets, nails, bolts, cramps, and dowels. 'And if we grant this, I do not see how we can help allowing Brunelleschi his iron chain round the dome of Florence, or the builders of Salisbury their elaborate iron binding of the central tower.'[2]

Nevertheless he holds that when iron enters seriously into the structure and framing of a building, that building ceases to be a work of architecture. It is with this view that most of us to-day must profoundly dis-

[1] Ruskin, *Seven Lamps of Architecture*, ii. xx. [2] *Ibid.*, ii. x.

agree. In every one of these chapters hitherto we have seen the great builders of the past testing, accepting, and finally beautifying new materials as they were invented, but never rejecting them merely because they were new and strange. It was easy for Ruskin in the cloistered seclusion of his study to jeer at the clumsy attempts of the Gothic revivalists to decorate cast ironwork that never should have been decorated, but he himself was partly to blame for his over-emphasis on ornamental features in architecture. Moreover, in his writings he says little about the wonderful wrought ironwork of the Renaissance, which displays ornament as beautiful and *as legitimate* as any carving on stone or wood. This was a convenient dodging of facts which must have been known to him.

The progress of building construction during the past fifty years has, however, very largely cleared up this vexed question of the architectural use of iron and steel. Cast iron is now only employed by reputable architects for utilitarian features, and if ornamented at all—as in the case of rainwater heads—the ornament is of suitable character and is sparingly applied. Wrought iron is adopted for decorative ironwork of a light nature, such as railings, gates, grilles, and brackets. For such purposes it is admirably suited, and may with propriety be decorated with all the grace and freedom that the craftsman of the past lavished upon it. Steel is now at last understood to be a powerful and rigid material, almost always to be concealed for reasons of protection against fire, always to be treated in design as part of the 'bones' of a building, and never—under any circumstances whatever—to be ornamented.

A study of the architecture of the past reveals a very sparing use of iron or of any metal on a large scale for purely constructional purposes until a century or so ago. Up to that time the only available metals were wrought iron and bronze, for the invention of steel is recent, though some form of steel is alleged to have been known to nations of the East thousands of years ago. This chapter, therefore, must be chiefly concerned with the lighter metalwork of old buildings, and must include some mention of bronze as well as of wrought iron.

The use of bronze (an alloy of copper and tin in the proportions of about 9 to 1 through most historical periods) has preceded that of iron among all civilized peoples. But there is no definite end to the Bronze Age, common to all countries, for in Egypt, for example, iron was introduced before the Christian era, whereas in backward countries it only became known through their discovery by Western explorers. The story of bronze is perhaps older than that of architecture, and long before we know anything certain about our own islands we have a record that the Phoenicians voyaged to our shores in search of copper and tin. In Egypt bronze was used for carpenters' and masons' tools, but not much for architectural purposes. Iron was introduced under the Ptolemies and the Romans, but was of slight importance in building, though it is recorded that the ceiling of a certain tomb was to be constructed of load-stone, so that its magnetic qualities would enable an effigy to be suspended from it in mid-air ![1]

But for once Egypt appears to have been preceded

[1] For early use of iron in Egypt, see Starkie Gardner, *Ironwork*, vol. i, pp. 27–30.

by Assyria, for iron was first used in Babylon in 1500–1000 B.C., and by the time of Nebuchadnezzar (sixth century B.C.) it had so far displaced bronze as to be used for the bolts and hangings of gates and for the cramps of a stone bridge across the Euphrates. In the British Museum there is a great iron bolt which formerly barred one of the bronze gates of Nineveh. Iron is mentioned several times in the Pentateuch, but bronze far more frequently. There is no doubt that the use of iron in India and China is of the highest antiquity, in fact it may have been introduced from the Far East to Mesopotamia, and carried thence into Egypt. There was a tribe in Pontus (a province of Asia Minor), known as the Chalybes, who are believed to have possessed the secret of making steel in very early times, and both in India and in China the process may have been mastered hundreds of years B.C.[1]

Among the primitive Greeks and the Cretans bronze was largely employed for decorative purposes, such as the lining of the walls of the Treasury of Atreus at Mycenae with bronze plates.[2] In later times it was used very extensively for statues, and in a less degree in architecture. The bronze dowels and cramps for masonry have already been described and illustrated (Figs. 46–56). Bronze was also used for doors, or for the casing of doors. Of architectural ironwork we have no remains, but written evidence proves that the Greeks understood and practised the arts of casting, forging, welding, embossing, polishing, inlaying, and tempering iron.[3] The Etruscans used bronze freely for wall-linings

[1] In Mesopotamia, *ibid.*, pp. 30–1.
[2] In primitive Greece, *ibid.*, pp. 32–3.
[3] *Ibid.*, p. 36.

and other decorative purposes. It is said that they understood even the process of damascening, but nothing is known of works in iron.[1]

Not until we reach the Roman period do we find iron used extensively in building. Bronze was still employed for a variety of purposes, constructional as well as decorative. Thus we have already noted the metal cramps in Roman masonry, the 'furniture' or fittings of doors, and actual doors either made of bronze or plated with bronze. The famous bronze doors of the Pantheon are still in existence. In a chapel at the Lateran are four large Corinthian columns of gilt bronze, dating from Roman times. The same material was very largely used for statuary and for decorative metalwork in general. The great Museum at Naples contains a magnificent collection of bronzes of all types from Pompeii.[2]

The Romans apparently used structural ironwork on a scale never reached again until the nineteenth century. At any rate, 'T-iron' girders have been discovered in the Baths of Caracalla suggesting the framing of a floor, and Professor Middleton,[3] writing of the same building, considered that he had found the recesses in the walls where the ends of great girders had formerly rested. This view is, however, discredited by Spiers,[4] who points out that such girders must have had a span of over 70 ft., which he regards as impossible in those days without intermediate supports. Some sort of iron and tile construction, perhaps not unlike some of our

[1] *Ibid.*, p. 44.
[2] *Ibid.*, pp. 36–49.
[3] Middleton, *Remains of Ancient Rome.*
[4] Anderson and Spiers, *Architecture of Greece and Rome*, p. 209.

'modern' fire-resisting floors, is described by Vitruvius [1] as a suitable ceiling for hot baths. Iron rods or arcs were spaced 2 ft. apart, suspended by iron hooks from an upper framing of timber, and between them tiles were fixed. Also, roof-trusses of bronze were used over the portico of the Pantheon and in some of the basilicas, but it is doubtful as to what extent these were of solid bronze and how far they may have been of timber plated with bronze.

The lighter ironwork of the Romans included window-bars, the grilles or railings of amphitheatres, casement windows, and the gates of the *fora*. Besides the more elaborate craftsmanship found in Rome itself, there were several flourishing schools of smithing in the provinces, notably in Gaul, of which we have many remains. London itself and many other Roman provincial cities have furnished sufficient fragments to allow us to form some idea of this work. Window grilles were provided with diagonal spikes as an additional means of protection (Fig. 152). Doors were hung on long strap-hinges with a pivot at one end (Fig. 155), the other end being sometimes plain and sometimes shaped into small scrolls. Figs. 153 and 154 show respectively a decorative clamp and a hasp from Gallo-Roman doors.[2] The British Museum contains many similar examples, and also a restored specimen of a Roman lock showing the mode of working.[3]

Recent discoveries on the site of Ariconium, an ancient

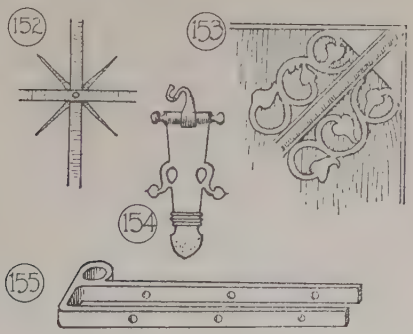
[1] Vitruvius, v. x.

[2] On Roman ironwork in England, see Gardner, *op. cit.*; and Lethaby, *Londinium*.

[3] See Fig. 151A in this book.

Roman city in the valley of the Wye, near Ross, have confirmed a local tradition which connected the district with iron smelting; and a report by Professor Turner of Birmingham University on the iron ore and slag discovered there was summarized as follows in *The Times* of 22 May 1923.

'During the Roman occupation of Britain the manufacture of iron and steel was conducted on a very considerable scale. A large military forge was erected



at Bath, and supplies of iron were obtained from the Forest of Dean, South Wales, and Yorkshire. Iron was produced in small hearths or forges, direct from ore, the fuel employed being charcoal. Nails and iron slag from the site were carefully examined, and it is stated that the slag has all the properties and characteristics of an iron slag obtained during the production of wrought iron at the present day. There is no doubt, it is added, that the samples examined were of artificially prepared material, as there is no iron ore in the neighbourhood of a similar kind, and it may be assumed with certainty that these samples were slag from the manufacture of iron by direct production, such as we know was conducted by the Romans. In a report on coal from the

site submitted to him, Mr. A. H. Lyell says that it is true coal, and that in all probability it comes from the Forest of Dean.'

The same authority adds that

'. . . during the digging it was noticed that in places beneath the soil there was a layer of gravel an inch thick, containing small iron clinker resting on red clay, which in turn overlaid the virgin red sand of the locality. This is so unusual that it is suggested that this gravel is the remains of floors on which iron was cooled by the application of water, and that the clay was laid beneath to prevent soakage into the porous sand, which would soon render the gravel floor spongy and unsuitable. It is certain that the clay was imported from some little distance.'

At all events, these discoveries have increased our knowledge of a very interesting and important period in the story of iron manufacture in this country.

We have already noted (in Chapter III) the Byzantine use of metal collars at the ends of marble shafts. Iron tie-bars were employed to strengthen arches. Of these perhaps the most important instances are to be found in the vaulting of St. Mark's at Venice. Bronze was also largely used for statues (that of St. Peter at Rome being a famous fifth-century example), altar-fronts, doors and their casings, grilles, and smaller details. Of Byzantine type are the altar-front of Aachen (of which there is a reproduction at South Kensington), and the doors of the cathedrals of Amalfi, Monte Cassino, Troja, and St. Mark's at Venice.

English ironwork of the Middle Ages has its origin in the Gallo-Roman school just mentioned. But Celtic metalwork was also influenced by Byzantium, and in

the ninth century came the Danes, who were expert blacksmiths, however small their production of architectural ironwork may have been. But their arrival had a curious negative effect on the craft in this country, English ironwork being designed for the most part to repel them! Hence it is that we find the blacksmith concentrating his energies especially on the door of the church that formed the natural refuge of each little community from these fierce pirates. The church door itself was very narrow and was made of one very thick plank of wood. It hung in reveals, and the scrollwork of the iron strap-hinges was so fashioned as to spring from the main horizontal strap at a point behind the face of the door-jamb, thus presenting additional resistance to an enemy trying to tear off the ironwork. Often the other end of the strap was continued behind the reveal farthest from the pin on which the hinges were hung. Two or three such hinges were fixed on each door. What we know of these early narrow church doors of the Anglo-Saxons is mainly derived from illustrations in contemporary manuscripts, but the door of Stillingfleet Church (Fig. 156), though as late as *c.* 1145, shows hinges disposed in similar fashion and with serpents' heads and Viking ships as ornamental features. Internally also these early doors were strengthened with defensive plating, and some were furnished with metal rims. Captured Danes were sometimes flayed alive, and their skins nailed to the church door.[1] The skin covering the door of the Chapel of the Pyx at Westminster is a souvenir of the robbers who broke into that treasury

[1] See paper by A. Way in the *Archaeological Journal*, vol. v, p. 185.

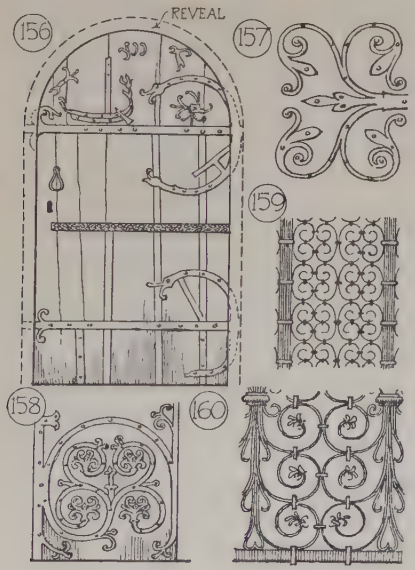
in 1303, and scarlet skins were used in later years behind iron scroll-hinges to perpetuate this cheerful custom. The heavily armoured doors of the Anglo-Saxon churches ceased to be necessary after the Norman Conquest. They are only found in England and in Scandinavia, not in the then more civilized countries of Central and Southern Europe.

The scrollwork of these ornamental hinges was conventionally and often clumsily treated, but in late examples there is an indication of the beautiful leaf-forms that followed in the thirteenth century. The remarkable and elaborate hinges from the north door of Durham Cathedral (*c.* 1135) include one frequently-repeated form, the Greek *palmette*, that is common in French work of the period, and it appears that they are the work of a French smith (Fig. 157).[1]

Other ironwork of the twelfth century comprised grilles enclosing chancels or chapels, for protecting the treasuries of cathedrals and churches. The former were of light and delicate workmanship but have nearly all perished, the only Romanesque example surviving being at Le Puy in France; and there are fragments of the St. Swithin grille (*c.* 1093) in Winchester Cathedral, of which Fig. 160, sketched from a reproduction at South Kensington, shows the type. The graceful scrolls are formed of iron $\frac{3}{8}$ in. to $\frac{7}{8}$ in. wide and $\frac{1}{8}$ in. to $\frac{1}{4}$ in. thick, strapped together with iron ties about $\frac{3}{4}$ in. wide. The heavy iron bottom bar is 1 in. by $\frac{7}{8}$ in. Moulded collars are used on the main vertical members. Fig. 159 shows a later example from Lincoln Cathedral, where small C-shaped scrolls are strapped to each other and to

[1] On early English iron hinges, see Gardner, *op. cit.*, pp. 59–76.

massive iron bars forming tall vertical panels. This closely resembles the grille round the central area or sanctuary of the Dome of the Rock at Jerusalem,[1] erected by the Crusaders during their rule in Palestine in the twelfth century, and is probably of the same date.



At South Kensington is another screen from Chichester of even lighter construction, with a row of tall spikes along the top.[2]

The grilles used over the window-openings of treasuries in the large churches were of far more massive construction, and were generally double, as in the example from

[1] M. S. Briggs, *Muhammadan Architecture, &c.*, Fig. 8.
[2] Gardner, *op. cit.*, pp. 77–83.

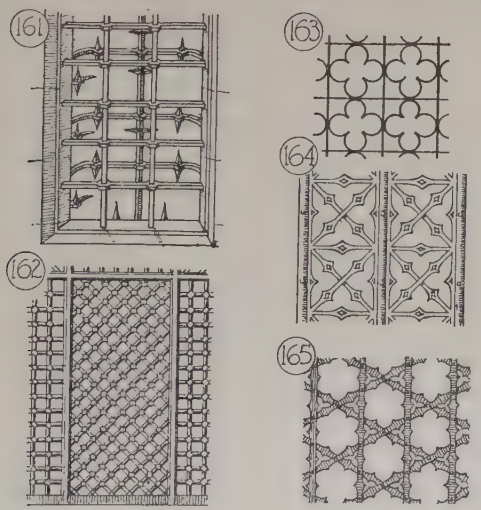
Canterbury illustrated in Fig. 161. The bars intersected at right angles, the vertical bars passing through eyes welded in the horizontal bars. The doors of the treasuries also were elaborately protected with heavy ironwork studded with nails, lined with plate iron, and furnished with strong bolts and locks. Up to comparatively modern times the iron industry of England had its chief seat in the Weald of Sussex, now one of the least industrial districts in this country. England was never rich in Romanesque bronzework. The famous sanctuary-knocker at Durham Cathedral is an example. At South Kensington are good reproductions of Romanesque doors from Verona, Pisa, Augsburg, and Hildesheim, dating from the ninth to the twelfth centuries.

Ironwork of the twelfth century in England was characterized by easy flowing scrollwork with foliated ends. The idea of protecting doors by means of iron hinges was now abandoned. A form of termination frequently used in this foliated work was a stamped rosette. To produce this ornament (according to Mr. Starkie Gardner, the chief living English authority on ironwork) it was necessary for the smith ' to strike the hot iron with prepared discs, as wax is pressed with a seal '.[1] Fig. 158 illustrates a portion of one of the earliest examples of foliated ironwork in England, the hinges of the entrance doors of Worksop Priory. In France during this century were made the wonderful hinges of the doors of Notre-Dame in Paris, strongly reminiscent of Roman ornament, and of such amazing beauty and delicacy that their authorship was ascribed to the devil.[2] Other fine examples of the period in this

[1] Gardner, *op. cit.*, p. 86.

[2] *Ibid.*, p. 90.

country are hinges at St. George's Chapel, Windsor, and the grille of the tomb of Eleanor of Castile in Westminster Abbey. The use of memorial brasses was first introduced into this country during the thirteenth century, and soon became general. Weather-vanes of iron were often erected on gables and spires, but as at



first they were fixed and had no pointers, they can have served no practical purpose!

During the thirteenth century a new wave of influence passed over English art, and nowhere is its effect more apparent than in the smith's craft. Again and again we have seen how the East taught the West in the early stages of art history, and now the Crusades played a part in influencing the development of ironwork. The English knights who fought in the Holy Land and in

Egypt learned from their Saracen foes much about armour and heraldry, but they also borrowed from them many new methods of craftsmanship. Frequent intercourse with Cairo, Palestine, and Constantinople brought our countrymen into touch with the marvellously skilled workers in those great centres of art. Indeed many writers consider that the influence of the Crusades was one of the most important factors in the making of our medieval architecture.

Our knowledge of Saracenic metalwork prior to the thirteenth century is chiefly derived from documents, for very few examples remain, and those are hardly architectural in character. There is at South Kensington, in the Salting Collection, a curious bronze vessel in the form of a grotesque animal. Others are found elsewhere, but of the decorative metalwork used profusely in palaces and mosques, according to contemporary writers, hardly anything has survived. However, the great schools of Cairo and Mosul are well represented in London, both at South Kensington and at the British Museum, by a large number of specimens of the metalwork in which their craftsmen excelled. These objects are chiefly noteworthy for the skill displayed in inlaying or 'damascening' bronze, a process applied not only to bowls, ewers, and other vessels of extraordinary beauty, but also to such architectural features as the facings or mountings of doors. These were chased and often inlaid with silver. A knocker usually formed part of the decorative scheme of the door. The window-openings of the mosques were filled with iron grilles, and great bronze lamps hung from the roofs.[1]

[1] On Saracenic metalwork, see my *Muhammadan Architecture, &c.*, pp. 220–4.

But the result of intercourse with the East, as it appears in ironwork of the fourteenth century, is not apparent in the form of elaborate damascening. It is rather evident in the prevalence of geometrical forms, so characteristic of Saracenic architecture. In the blaze of an Eastern sun, such geometrical forms were mainly used in surface decoration, to break up a flat surface that would otherwise be unpleasantly glaring to the eye. But they were also adapted to the wooden lattices (*mashrabiyyah*) described in the last chapter. It is, then, in the design of iron grilles, used for enclosing chantry chapels or tombs, that Eastern influence is most striking and obvious. Typical examples are illustrated in Figs. 164 and 165, both sketched from examples at South Kensington. The former is divided into 6 in. squares in which light diagonal pieces are inserted. Between the squares are vertical moulded bars, probably imitated from joiners' work. In Fig. 165 the construction is that of a light lattice with flat bars $\frac{3}{8}$ in. thick and $\frac{3}{8}$ in. to $\frac{3}{4}$ in. wide, secured together with metal pins; the lattice bars are 4 in. apart. Eastern influence is still more apparent in the grille from St. Alban's Abbey (Fig. 162), which is a close imitation of the typical Cairene *mashrabiyyah* or lattice-work described in the last chapter. Here the construction is of semi-circular bars $\frac{3}{4}$ in. wide, bolted together at every intersection by means of metal pins with ornamental heads.

Fig. 163 shows a grille from Chichester, divided into $4\frac{3}{4}$ in. squares, each containing a quatrefoil. The ironwork of this example is only $\frac{1}{8}$ in. thick and of narrow width. The quatrefoil pattern may be derived from Byzantine grilles or 'roundel' glazing, as found at

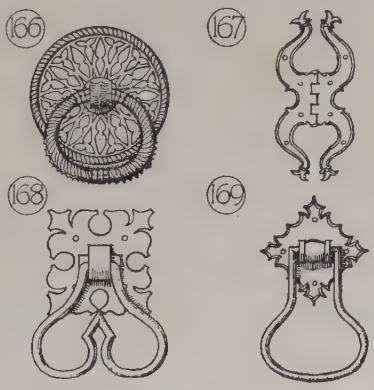
St. Mark's at Venice and elsewhere. Saracenic influence is found in other kinds of decorative ironwork, as, for instance, in the door-handle from Stogumber Church, Somerset, illustrated in Fig. 166, while another English example [1] is actually inscribed with Arabic characters, which lend themselves naturally to decorative treatment.

Meanwhile the production of much graceful wrought ironwork continued, flowing scrollwork being used as well as the geometrical patterns just described. The sharply-pointed spikes or 'prickets', forming a cresting above the top rail, enclosing chantries, doubtless had a defensive object, but were also used to carry tapers, and hence, although the spikes may be clustered, their barbs are always vertical. Late Gothic churches must have contained a great deal of such ironwork, and, as it was not regarded as of much value at the time when so much church-furniture was destroyed, we must assume that it has perished by the natural processes of age and decay. Heavier ironwork was used in castles, where the heavy timber portcullises and the stout entrance-doors were respectively shod and sheathed with metal. In many Northern castles heavy iron lattices or 'yetts' (gates) were used as inner gates instead of the usual portcullis. But even before the end of the fourteenth century the English smith had lost his position of pre-eminence, and, until the time of Tijou, when the ironwork of this country again far surpassed that of all others, he became inferior to the craftsmen of Flanders, Germany, Italy, Spain, and France. A visit to the South Kensington Museum establishes this fact beyond doubt. England produced, during two hundred years

[1] Gardner, *op. cit.*, p. 122.

or more, nothing comparable with the wonderful masterpieces of the German locksmiths or with the Spanish 'rejas' or grilles. Flemish smiths were brought to England, and one of their most famous examples is the gate (1515–33) of Bishop West's chapel in Ely Cathedral.

Nothing has been said so far in this chapter of the districts of England whence iron was obtained in early days, or of the methods used. It was essential that it



should be found near the surface of the ground, and also that there should be an abundant supply of wood fuel hard by for smelting. Hence the chief ironfields prior to the introduction of coal were the Forest of Dean, Sherwood Forest, Northamptonshire, and the Weald of Sussex. All of these, and many more, were known to the Romans, and may have been used long before their arrival. The first-named was the chief source of supply. There were great pits and galleries, also vast heaps of cinders which have since yielded much iron to later enterprise, for the Roman smelting left

a large residue of iron in the stone. The industry in the Weald was of later date and of less importance, though undoubtedly of Roman origin, but with the evacuation of Britain it appears to have fallen into disuse until the thirteenth century, when documents prove it to have been revived again.

'A cast iron grave slab', writes Mr. Starkie Gardner, 'is the only indication of a revival of the industry in the fourteenth century, but wrought iron may well have been produced in the Weald at a considerably earlier period. In those times iron was produced from the ore in a furnace, with bellows of leather and wood; while to convert the "bloom" into merchantable iron needed further process in a forge, the hammers employed to convert it into bars being "tilt" or lever worked by water-power. The furnace and the forge were separate buildings and establishments, and were invariably kept distinct in documents, even though worked by one owner: who might possess two furnaces and one or more forges. Diggers, carters, ostlers, wood-cutters, charcoal-burners, stokers, puddlers, moulders, smiths, mates, in all some 65 men were required for a furnace and forge, of which there were at least 150 or more in the Weald in the days of its prosperity.'[1]

The rapid development of artillery in Tudor times must have diverted the energies of many smiths into the manufacture of ordnance, nor did ironwork play any important part in the architecture of the sixteenth or early seventeenth centuries. Nevertheless it did change its character in many details, as was natural in view of the great change that came into architecture as a whole. Church-building, for the greater part of the period, was dead, and such developments as took place were chiefly

[1] Gardner, *op. cit.*, vol. iii, pp. 180–1.

associated with the increased standard of comfort in dwelling-houses large and small. Thus door-furniture had to be modified to suit the light panelled doors that replaced the heavy structures requiring strong iron strap-hinges on pins. Hence we find that the cockspur or 'cock's head' hinge (Fig. 167) was introduced, capable of a great variety of ornamental treatment, and allowing a door to be hung to panelling instead of being pivoted in a solid stone jamb. The heavy handles or knockers used on medieval church-doors were replaced by a lighter and more graceful type (Figs. 168 and 169) usually consisting of a pierced square plate, fixed either vertically or diagonally, with a drop-handle serving also as a knocker, and hanging perpendicularly from the spindle. For internal doors light lifting-latches were often used, frequently with pierced plates. On heavy doors such as those at the entrance to large houses, churches, or colleges, the massive bolts and bars of medieval days continued in fashion. But though the art of the locksmith, as has already been noted, never attained in England anything like the perfection reached by the German and Flemish craftsmen, very ingenious and elaborate locks were produced in this country in the Tudor period, with ornamental escutcheons and keys.

Nothing was more typical of the change in domestic life during the sixteenth century than the great increase in the number and size of windows, now freely used to admit sunshine into all parts of the house without any regard for the old idea of defence. And as windows increased in number, attention came to be devoted to the details of their design. Not only was heraldry introduced into the leaded glazing of the chief apart-

ments of the greater houses, but even the modest casements of small cottages were provided with latches or catches of charming design, usually formed of a pierced plate with a lifting-latch controlled by a spring which is worked by a handle or ring. One of these latches or casement-fasteners is illustrated in Fig. 231.

During the same period the medieval fireplace in the centre of the Great Hall had completely given way to the later type against a wall. To protect the brickwork or masonry at the back of the fireplace, where exposed to the flames, iron 'fire-backs' came into use. These were ornamental plates of *cast* iron, possibly made in the Weald of Sussex as early as the fourteenth century, certainly popular by the sixteenth. Casting, for centuries a lost art, was rediscovered in the Weald, and a flourishing new industry was established. Similar prosperity favoured the Forest of Dean. The iron was cast on a flat bed of sand, into which were pressed or stamped numerals (for dates), rosettes, and other ornamental features to relieve the flat surface. This primitive method explains the irregular placing of such ornaments, and also shows us why the numerals of dates are sometimes transposed or upside down, suggesting the products of a child's printing-press. The 'cable-moulding' of the border was made by pressing an ordinary hemp rope into the sand of the mould. By the end of the sixteenth century proper 'patterns' were used in the sand-mould, the Royal Arms being a favourite subject. Some elaborate patterns were imported from Flanders. Other accessories of the fireplace were andirons, often made in Wealden cast iron from the sixteenth century onwards.

Though few churches were built during this period,

ambitious tombs in stone and marble were erected in great profusion within existing churches, and thus the development of enclosing grilles and railings ('grates' as they were called) continued. The usual type consists of plain vertical bars let into the underside of a hollow cornice, formed like a box of four flat bars. Into the flat top bar of the cornice are rivetted the spikes continuing the lines of the vertical bars below. Ornamental mouldings and heraldic emblems adorn the cornice, and colour and gilding are freely used. At the angles of the tomb are stout standards. Of a very different character are the pierced gratings that protect the bookshelves in the Bodleian Library at Oxford.

All the sixteenth- and seventeenth-century ironwork described so far has been for internal use. The appearance of ironwork outside buildings heralds the new epoch, for now the cult of gardens, of which Bacon writes so attractively,[1] had created a new need, and, in place of walled courtyards closed by heavy iron-shod gates, there arose a demand for open vistas across parterres and lawns. But some form of protection was necessary, if only to ward off stray dogs and cattle. At first wooden gates formed the entrance to the forecourts of country houses, then by gradual stages the panels were filled with plain vertical iron bars, the frame itself came to be made of iron, and finally the ironwork all became light and flowing, offering no obstruction to the view, yet serving its purpose as a gate. Iron railings were fixed on the stone parapets of the bridge over the Medway at Rochester in 1543, and a century or so later iron balconies (already in common use in Italy and

[1] Bacon's *Essays*, XLVI, 'Of Gardens' (1625).

elsewhere on the Continent) came into fashion. We have now reached the point at which English ironwork suddenly entered on a new phase, leaving all its continental rivals (for centuries its superiors) far behind.

This remarkable advance is universally ascribed to the genius of one man, Jean Tijou, whose name hardly leads one to suspect him of English birth, but whose nationality is doubtful. He arrived from Holland in the train of William of Orange in 1689, and was at once employed to make an iron balcony in the gardens at Hampton Court, then being laid out by French architects under the personal supervision of the Queen. But, before his appearance, signs of the coming movement had already manifested themselves. After the Great Fire, iron balconies were insisted on in the principal streets of London, their size and construction being definitely laid down. In these and in contemporary railings scrollwork is occasionally found. The tulip became a favourite emblem in ironwork of the third quarter of the seventeenth century. Another innovation was the use of 'dog-bars', narrow vertical bars with javelin heads placed intermediately between each pair in the lower part of gates or railings, to prevent dogs getting through. Over large double gates was placed an 'overthrow', a scrollwork design rising to the centre from each gate-pier, and usually containing as its central feature the arms or monogram of the owner. Many of the sword-rests and mace-rests of Wren's City churches are earlier than Tijou's day, but are extremely light and graceful.

But Tijou introduced a new method of treating decorative ironwork, and the finest examples of his

craftsmanship are still to be seen at Hampton Court, in spite of many subsequent alterations and removals. Scrollwork had hitherto been used sparingly and with hesitation. He developed it into bold and flowing designs of extraordinary beauty, using sheet iron beaten into the form of acanthus leaves, masks, and heraldic emblems with great freedom, and combining with it the ordinary bars and scrolls of smiths' work. The amount of work executed by him at Hampton Court was prodigious, for the length of the railings round the great formal gardens was many hundreds of yards, and, though naturally the major part of this length consisted of plain railings, yet ornamental panels, pilasters, and gates were largely used. During the years that he spent in England he carried out extensive commissions in many of the great country houses, but perhaps his best-known work is to be found in St. Paul's Cathedral, executed from 1691 onwards. His first consignment, according to Mr. Starkie Gardner,

'. . . consisted of the iron frames for the large ground-floor windows, charged at *6d.* per pound, equal to about £48 each, exclusive of two vertical iron stays filled in with alternate circles and lozenges charged as "grotesque". Tijou made the whole of the lower tier of windows, and all above those in the choir, transepts, and west front, his deliveries of these extending to 1697.'[1]

This quotation shows that, in spite of his modern reputation as a great artist, Tijou nevertheless carried on the more prosaic and utilitarian branches of the smith's craft. It is, however, for his decorative iron-

[1] Gardner, *op. cit.*, vol. iii, p. 87.

work that he is celebrated. At St. Paul's this included the whole of the magnificent ironwork in the choir, the altar-gates, the organ screen (now refixed in the form of ambulatory screens), the balustrades and gates of the geometric stairs (at 22*s.* 6*d.* per foot), and external gates at the south entrance of the cathedral.

Finally he retired to Paris and died there in obscurity. It is stated that he was not personally a smith, and this may explain the alleged impracticability of some of the designs that he, like other craftsmen of his day, published in book form. But he set out his own work, or much of it, with his own hand, as is evident from an account preserved at St. Paul's, which records that Hopton, a joiner, was paid 'ffor gluing of Boards for Mr. Tijoue to draw ye iron screene upon'.[1]

Powerful as was the influence of Tijou on the design of domestic ironwork, the craftsmen who followed him soon abandoned the plentiful employment of embossed sheet-metal that was so French in character in his work, and reverted to the more sober use of scrollwork formed of flat or square bars. Very typical of this English school are the fine gates from Carshalton Park, illustrated in Fig. 170 from a measured drawing of my own made before their removal many years ago. The construction of ironwork of this type was generally sound. The main horizontal bars were tenoned into the main vertical bars, and the lighter vertical bars into the main horizontal bars. The lower parts of gates and railings were filled with light vertical dog-bars, generally deeper than their width on the face and spaced about 1½ in. apart, with light javelin heads welded to the ordinary vertical bars.

[1] Gardner, *op. cit.*, vol. iii, p. 88.

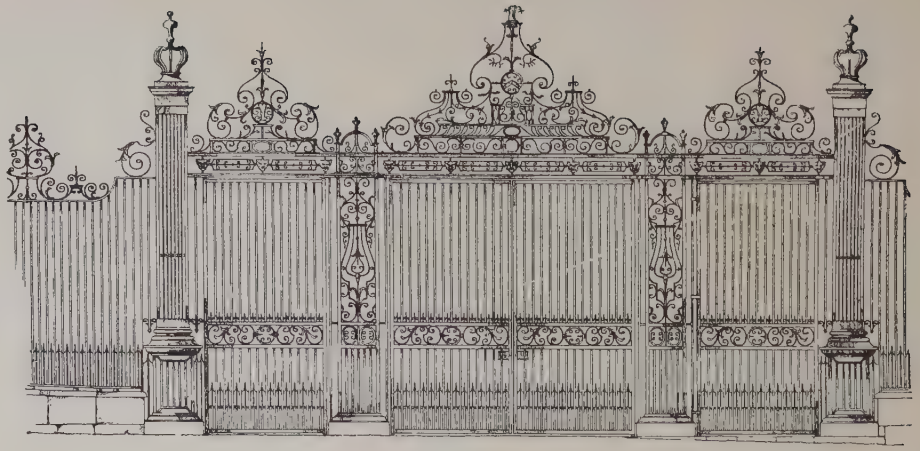


Fig. 170. Wrought iron gates and railings from Carshalton Park, Surrey
(*Measured and drawn by the Author*)

The 'overthrow', or fixed ironwork above the gates, was invariably the lightest and most graceful part of the design. Locks were plain and solid, but a scrolled lock-rail is often found. Two types of pilaster were used: the flat openwork panel, filled with a lyre pattern and often stiffened at the back with stout struts; and the open pier, square on plan, formed of heavy bars, and with a capital and base of moulded sheet-iron. Where a stone base was used for the railings the bars were caulked in. All these features are illustrated in Fig. 170.

In previous chapters of this book insistence has been laid on the charm of simple craftsmanship untrammelled by copybooks and rules. It can hardly be said that English ironwork of the first half of the eighteenth century was simple; on the other hand it was in no way formal, and in spite of the elaboration and studied grace of its design, practical requirements were never forgotten. Strength was provided where it was required; lightness was reserved for positions where rigidity was not so essential, as in overthrows and intermediate panels; and in their treatment of utilitarian dog-bars the English smiths made a virtue of necessity. All over our country are preserved examples of this perfect craftsmanship, not only in gates and railings, but also in staircase-balustrades, balconies, lamp-holders, weather-vanes, brackets, and minor features.

After the middle of the eighteenth century the smith became more and more the servant of the architect, who at that time was chiefly concerned with precedent as laid down by his copybooks. As these invaluable tomes contained Roman rules for masonry and next to nothing relating to ironwork, it is hardly wonderful that a decline

set in. The graceful scrolls of the smiths gave way to a heavier and more rigid type of design, with all the native charm of the earlier style removed. Neither Vitruvius nor Palladio is particularly helpful in supplying 'inspiration' for the design of such work. Meanwhile the making of cast-iron fire-backs and andirons in the Weald and elsewhere had gradually died out, for grates made of metal had now been introduced.

To some extent there was a revival of craftsmanship in iron under the brothers Adam towards the end of the eighteenth century, though by that time design was entirely in the hands of the architects. The grilles in the semi-circular fanlights over the front-doors of many London houses are of delicate workmanship, but there was a tendency to repetition of all ornamental features, which were now often made in cast iron, in bronze, or in lead. Greek ornaments were freely copied, and these lent themselves to repetition in cast iron. But by this innovation the death-knell of craftsmanship was sounded and the personality of the smith was completely stifled. The most attractive metalwork of this period is to be found in the fire-grates and fenders of bright steel, which though designed by the architect, often show great variety and charm. Some have a detachable and ornamental 'summer-front', so made that it can be removed, leaving the more serviceable grate behind for use in winter. The hob-grate was largely used in the second half of the eighteenth century. It was made of cast iron with bars of wrought iron. Many of these grates were manufactured in Scotland, where the Carron Foundry was established in 1759. The ornamental treatment of the cast iron was delicate and refined, very different

from the rough modelling of the Wealden fire-backs, but it was well suited to its purpose, as they were in their own way.

Joseph Moxon, from whose book *Mechanick Exercises*, published in 1678, I have quoted in previous chapters, devotes his first chapter to describing the craft of the smith as it was practised in his own day. 'Smithing', he writes, 'is an Art-Manual, by which an irregular Lump (or several Lumps) of Iron, is wrought into an intended Shape.' Then follows an account of the various tools and appliances used by the smith (Fig. 170A). He describes the forge, which usually has a brick base 2 ft. 6 in. or 2 ft. 9 in. high, with hollow arches under, and is furnished with an iron 'hovel' (hood) and chimney, and with a bellows worked by a lever-rod. He also mentions the anvil, tongs, hammer, sledge, vice, hand-vice, 'plyers', drill, drill-bow, the screw-plate and its taps. Discussing 'the Several heats Smiths take of their Iron' he observes that 'Blood-red Heat' is to be used when the iron has already assumed its final form but needs a little hammering to smooth it; 'Flame, or White Heat', when iron has to be forged into its form and size; and 'Sparkling, or Welding Heat' only when you are doubling up two bars or pieces of iron to make them into one piece, or making several bars into one. Brazing and soldering, he says, are only employed by smiths where work is too thin or small to be welded.

As regard materials, he states that English iron is mostly coarse, hard, and brittle, chiefly suitable for fire-bars, &c., unless it comes from the Forest of Dean or 'some few places more'. He adds that ironstone occurs in most parts of England, but that so much *wood*

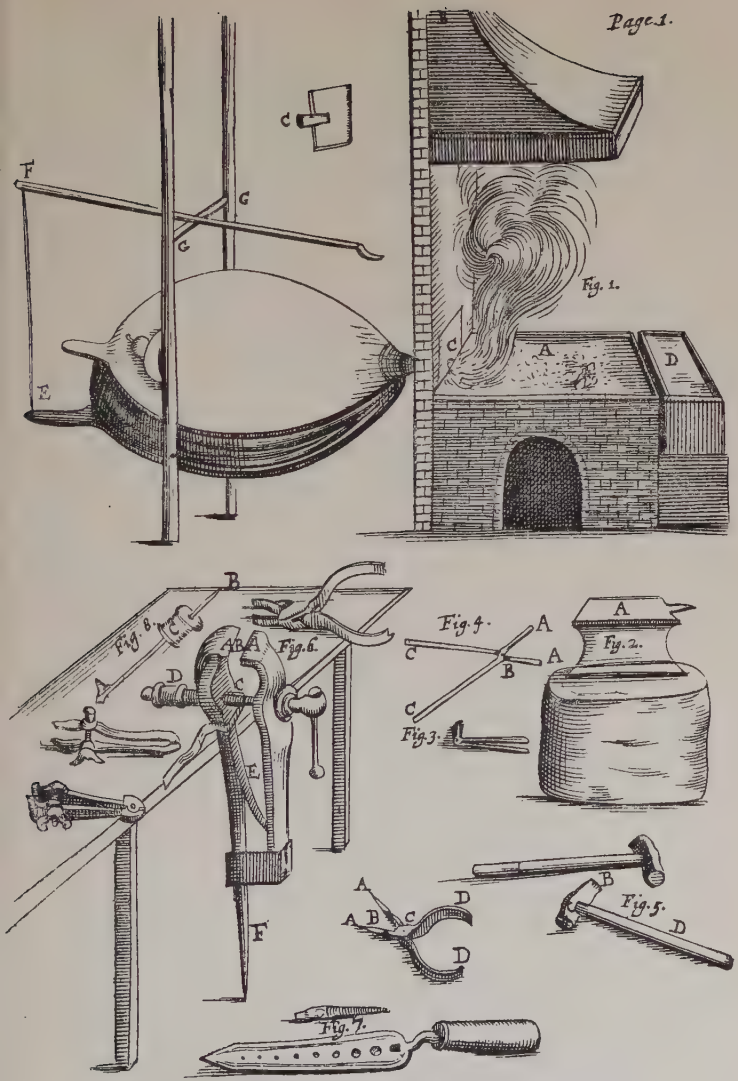


Fig. 170A. Smiths' Tools (from Moxon's *Mechanick Exercises*, 1678)

is required ' to draw the Iron from them ' that it is not profitable to work everywhere. Swedish iron is the best used in England, and Spanish would be as good, but that it is liable ' to crack betwixt hot and cold '. It is also ' unevenly wrought in the Bars ' so costs a good deal for smoothing, but is suitable for anvils, sledges, and hammers. There is some iron that comes from Holland and is called ' Dort Squares ', but it is made in Germany. It is imported in bars $\frac{3}{4}$ in. square, and is only fit for window-bars, fire-bars, &c. His remarks on steel are worth quoting in full, though of course in his day steel was not used structurally, but only for tools, &c.

' The difficulty of getting good Steel makes many Workmen (when by good hap they light on it) commend that Country-Steel for best, from whence that Steel came. Thus I have found some cry up *Flemish-Steel*, others *Swedish*, *English*, *Spanish*, *Venice*, &c. But according to my Observation and common Consent of the most ingenious Workmen, each Country produces almost indifferently good and bad ; yet each Country doth not equally produce such Steel as is fit for every particular purpose, as I shall shew you by and by. But the several sorts of Steel, that are in general use here in *England*, are the *English*, the *Flemish*, the *Swedish*, the *Spanish*, and the *Venice-steel*. The *English-steel* is made in several places, as in *Yorkshire*, *Gloucestershire*, *Sussex*, the *Wild of Kent*, &c. But the best is made about the *Forrest of Dean*, it breaks Fiery, with somewhat a course Grain. But if it be well wrought and proves sound, it makes good Edge-tools, Files and Punches. It will work well at the Forge, and takes a good Heat. The *Flemish-steel* is made in *Germany*, in the Country of *Stiermark* and in the *Land of Luyck* : From thence brought to *Colen*, and is brought down the River *Rhine* to *Dort*, and other parts of *Holland* and *Flanders*, some in *Bars* and some in *Gads*, and is there-

fore called by us *Flemish-steel* and sometimes *Gad-steel*.' . . . 'It is used for watch-springs, punches, and file-cutters' chisels.' . . . 'It breaks with a fine Grain, works well at the Forge, and will take a welding Heat.' . . . 'The *Spanish-steel* is made about Biscay.' . . . 'It is too brittle for Springs or Punches, but makes good fine Edg'd-tools.'

He explains that the so-called Swedish steel comes from 'Dantzick' and resembles Flemish steel; that 'Venice-steel' is chiefly used for razors and surgical instruments; and also mentions the steel blades of Damascus, but admits that he can get no authentic facts about them. He concludes with 'The Rule to know good Steel by': 'Break a little piece of the end of the Rod, and observe how it breaks; for good Steel breaks short of all Gray, like frost work Silver. But in the breaking of the bad you will find some veins of Iron shining and doubling in the Steel.'

In regard to workmanship, he describes the process of filing in general, and then the making of hinges, locks, keys, screws, and nuts. Among hinges he includes the 'Cross-garnet' type, also 'Duftails' and 'Side-hinges', but not butts, or strap-hinges, as we know them. The locks include stock-locks (for outside doors), spring-locks (for 'chamber-doors'), cupboard-locks, &c. He then digresses on rivetting, and next passes to 'The Rules and manner of Cutting Worms upon great Screws'.

Lastly we may note his description of the method by which iron is twisted, for in that work lay much of the charm of the smithing of his day.

'Square and flat Bars, sometimes are by Smiths, Twisted for Ornament. It is very easily done; for

after the Bar is square or flat Forg'd (and if the curiosity of your Work require it truly Fil'd) you must take a *Flame-heat*, or if your Work be small, but *Blood-red heat*, and you may twist it about, as much or as little as you please, either with the *Tongs*, *Vice*, or *Hand-Vice*, etc.'

Early in the nineteenth century the development of decorative ironwork had come to an inglorious end, but by that time cast-iron, the real cause of its downfall, was assuming a new importance as a constructional material in building. From the later days of Rome to the end of the eighteenth century structural ironwork was hardly known. Beyond the minor functions that Ruskin regards as legitimate for this despised material, few instances are recorded of its use. It was employed in the spire of Salisbury Cathedral, in the dome at Florence, and, more definitely as a structural factor, in the dome of St. Paul's. But in none of these cases was any of the chief ' bones ' of the building formed of iron. In the last quarter of the eighteenth century two large iron bridges were erected in England, which are still in good condition, and in 1833 a floor of cast-iron joists and concrete was produced. Long before this, iron girders had been used in a Manchester cotton-mill, and in 1850 the rolled-iron joist was introduced into this country from Belgium. Finally came the Crystal Palace, designed to house the Great Exhibition of 1851.

During the seventy years that have elapsed since that date, the development of iron and then of steel construction has proceeded apace, but the proper treatment of the material in design is still perhaps the most difficult problem in modern architecture. The architect lives with one eye on the past, and, in this case at

least, the past affords him no very obvious inspiration. He is still groping among the great marble columns of the Parthenon for light on modern commercial buildings. But if he regard the spirit rather than the letter of the past, he will see that the ancients were always modern. The village blacksmith laboured to keep out the savage Danes by strengthening the church door, and centuries later he introduced dog-bars to keep out the dogs. Yet in doing so he never ceased to be an artist. He designed the most beautiful ironwork in all art-history in the first half of the eighteenth century, when he had no copybooks, and it was not until the Architect came with his Vitruvius under his arm that all life and originality vanished from the work.

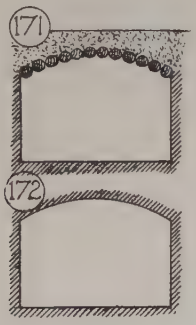
VIII

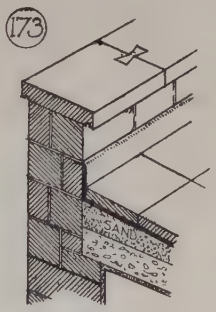
ROOF COVERINGS

In no branch of architecture is the effect of climate and of available material more evident than in the design of roofs. South of the Mediterranean the normal type was flat, in Italy and Greece a low pitch was found necessary, and in Northern Europe—so long as building followed its natural course—a steep slope was the accepted form, culminating in the precipitous roofs of Norway and of the old gabled houses of Prussia. But the revival of Roman fashions during the Renaissance brought the low-pitched roofs of Greece and Italy into higher latitudes than the ancient tradition had allowed, and the adoption of Welsh slates—or even less worthy materials—during the past century has broken the tradition of English roofing altogether.

In Egypt two types of roof were used : the huge slabs of stone employed in the temples, borne on immense columns or piers ; and the flat mud roof on a ceiling of date-palm trunks laid close together. The former were ceilings rather than roofs, and are related to the marble ceilings of Greek temples and to the stone ceilings of Syria during the late Roman period. Nor have they much influence on the development of roof-construction properly speaking, for little if any provision is made for dealing with the effects of rain and snow, and it is with such provision that we must be mainly concerned in this chapter. The camber given to the palm-trunks in the

second type of roof (a sound precaution showing a knowledge of thrusts) may have suggested the curved ceiling of the typical Egyptian rock-tomb, as shown in Figs. 171 and 172. It cannot be pretended that the flat roof, still used on every mud-built hovel in the country, is proof against the rain-storms that appear in the parts of Egypt that lie near the sea. In a cloud-burst that occurred near Cairo shortly after the end of the war, a number of houses collapsed through faulty construction, and there





was some loss of life. Yet most modern buildings in the cities have flat roofs of some form of concrete, supported on squared palm-trunks in the poorer houses, and on steel joists in good work. But the flat surface exposed to the sun is still a problem. Concrete is liable to crack, asphalt is certain to melt, and for some good modern buildings the type of roof illustrated in Fig. 173 has been adopted. Reinforced concrete, or terra-cotta blocks carried on light steelwork, form the substructure. On this a bed of sand is ' laid to falls ', then a layer of asphalt giving the necessary protection against damp, and finally a layer of large square white tiles, made

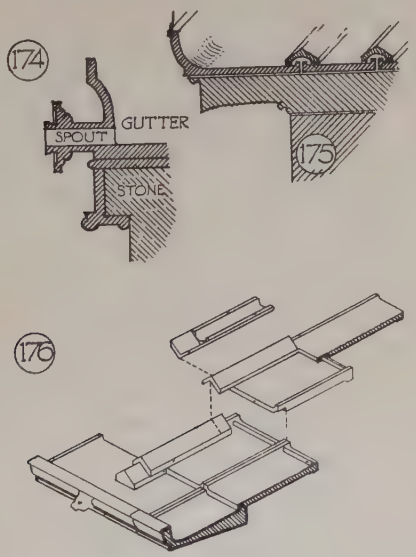
locally and known as *balat* (i. e. 'local') paving, this serving to protect the asphalt from the sun.

Flat roofs of tree-trunks, covered with some form of mud or cement, perhaps sometimes 'laid to falls', appear to have been used in Assyria, Persia, and primitive Greece. Probably the flat Minoan roofs in Crete, and those of Mycenae, were weathered from the centre to the walls, the fall being obtained by making the *pisé* or mud thicker in the centre, and thus a central aisle of pillars was sometimes necessary to support the increased weight.[1] But long before the age of Pericles we find the sloping roof adopted for Greek temples and other important buildings. (See Chapter V.) The usual covering materials were tiles of marble or of terra-cotta. The latter were often used in early temples. Fig. 174 shows how terra-cotta was used in the Treasury of Gela at Olympia. This is a rare example of the application of terra-cotta casing to a core of masonry, but in many Greek and Etruscan buildings terra-cotta was used to protect the timbers of the entablature as well as to cover the roof. In the temple of Athena at Aegina most of the tiles were of terra-cotta, but those of the pediment and of the cymatium were of marble. The heavy timber roof of the Arsenal at the Piraeus, illustrated in Fig. 101 (Chapter V), was covered with Corinthian tiles bedded in mortar on close boarding, their under-surfaces being rarely true.

In marble tiling, large slabs were usually carried on an open framework of timber, with narrow ridged tiles covering the vertical joints. Figs. 175 and 176 represent two examples of this type, from the Parthenon and

[1] Bell, *Hellenic Architecture*, pp. 63, 113.

from the temple of Rhamnus respectively. Occasionally, as at the temple at Bassae (according to Cockerell [1]), the covering ridge was worked on the flat tile, but this must have been an expensive method. At the ridge the two sloping surfaces met against a marble ridge-tile.



At the eaves *antefixae* were sometimes used to terminate the covering fillets. Water at the eaves generally ran off through ornamental spouts or gargoyles of various types (Figs. 174 and 176). The invention of marble tiles is variously ascribed to the fifth or sixth centuries B. C., and is attributed to Naxos, where was found emery, a material that would serve for the purpose of sawing

[1] Quoted in Simpson, *History of Architectural Development*, vol. i, p. 88.

up the marble blocks. It is possible that the transparency of the Parian marble accounted for its use in the Parthenon and in most Greek temples, for thus may have been partially solved the vexed question of lighting these buildings. In the temple of Apollo at Bassae were found the largest marble tiles known, 3 ft. 6 in. by 2 ft. 1¼ in., and 18 in. thick. One of these was pierced with an opening, of which the exact size is not known, but it was not less than 20 in. by 11 in., and perhaps much more. This was presumably an aperture, or part of an aperture extending over several tiles, to admit light. Round the edge of the opening was a raised rim to prevent water flowing in, the amount of rain-water that would fall directly on the temple floor being negligible. On rounded surfaces, such as the domical top of the Monument of Lysikrates, the Greeks used marble tiles of scale-form.[1]

The Romans closely followed Greek precedent in their use of roofing materials. Tiles of marble and terra-cotta, sometimes with *antefixae*, were employed, also 'fish-scale' tiles on some buildings (e. g. the tomb of the Julii at Saint-Remy). Copper plates were used on the Pantheon, and lead on a temple in Auvergne. Among the Roman remains found in England are numerous tiles. Some of these had turned-up edges, cut off near the top to allow the next tile to lap over; the flanges were covered with half-round tiles, tapering upwards so that one lapped over another. Others, as illustrated on Fig. 176A, were oblong *tegulae* about 17 in. by 14 in. and about 1 in. thick, of coarse red

[1] On Greek roofing-materials, see Simpson, *op. cit.*, and Choisy, *Histoire*, vol. i, pp. 282–3.

pottery, with flanges along both the longer edges, and a half-cylinder (*imbrex*) placed over the flanges of two adjacent tiles as just described. The example illustrated

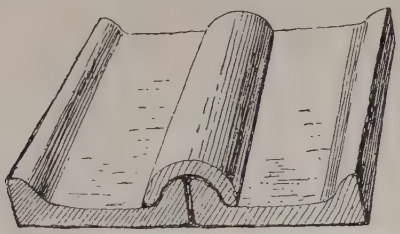


Fig. 176A. Roman roofing tiles, London

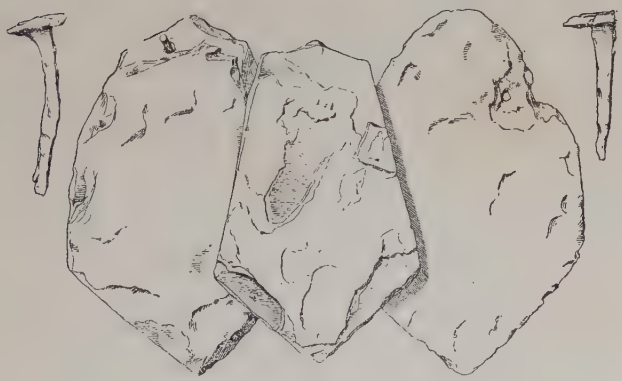


Fig. 176B. Roman stone slates, Dorset

was found in London, but there are many similar in the Guildhall Museum, in the York Museum, and elsewhere. Some of these tiles had a single nail-hole near the top, and they were fastened by pegs or iron nails to the rafters. A tile ridge or cresting was also used.

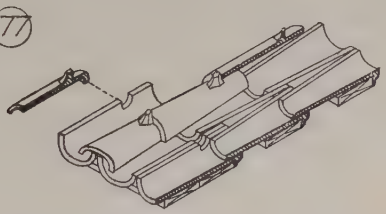
The Romans also used stone slates in Britain, and thatch for unimportant buildings. Fig. 176B illustrates stone roofing slates from Fifehead Neville, Dorset. The slates were thick, and of pointed shape below, like some modern asbestos tiles, thus producing the effect of diagonal lines on the roof. Stone ridges have also been found, with stone knobs or finials on the gable-ends towards the street. Vitruvius has very little to tell us about Roman roofing materials, but he devotes a couple of pages to a study of primitive roofing, and mentions incidentally a building on the Areopagus at Athens with a mud roof, and also the thatched 'Hut of Romulus' on the Capitol at Rome.[1]

Byzantine timber roofs were covered with half-round Italian tiles like those illustrated in Fig. 177, and tiles were laid on the extrados of domes in late work. The domes of St. Vitale and of the Baptistery at Ravenna have low-pitched tiled roofs of timber to protect them from the weather, but generally Byzantine domes were exposed externally and were covered with cement or lead.[2] The Dome of the Rock at Jerusalem was covered with gilt bronze, so dazzling—according to contemporary writers—that it was impossible to look at it in sunlight; in winter it was protected from rain and snow by a sort of huge tarpaulin of skins. Romanesque roofs were occasionally covered with plates of metal (in one case of tin), but half-round tiles were the usual material, of the type illustrated in Fig. 177. Such tiles were used in

[1] On Roman roofing materials, see Vitruvius, II. i; Choisy, *op. cit.*, vol. i, p. 534; and Lethaby, *Londinium*.

[2] On Byzantine roofing-materials, see Simpson, *op. cit.*, pp. 216–18; Jackson, *Byzantine and Romanesque Architecture*, vol. i, p. 48.

Italy throughout the Middle Ages and the Renaissance, also in Southern France and in Spain, where the low-pitched type of roof is found. In other parts of France, where Romanesque roofs reached a pitch of 45 deg. or more, it is possible that slates were used. In England tiles were normal, but lead and other materials were also employed. Two striking developments of Romanesque roofing on the Continent were the gabled German spires common in Rhineland churches (represented in England by the little Saxon spire at Sompting


177

in Sussex), and the domes, turrets, and spires decorated with 'scaled' patterns, found on large churches at Périgueux, Poitiers, Angoulême, and Saintes. These churches are earlier than the sculptured domes of the fifteenth and sixteenth centuries in Cairo, and may conceivably have inspired the latter.[1]

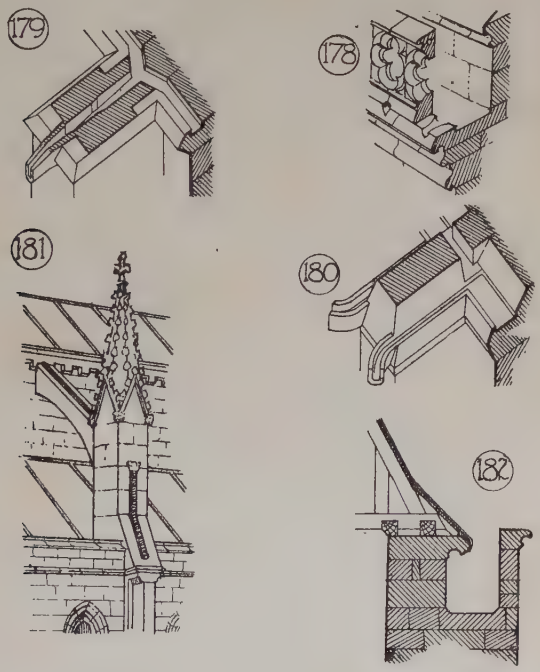
The steep-pitched roofs of Gothic buildings were covered with slates, with lead, or with tiles provided with nibs. In England wood shingles were used in timber districts, stone slates in stone districts, tiles elsewhere, and lead was not common till the later periods, when it was found that it enabled the steep pitch, required for the older materials, to be lowered. On the tower of

[1] Choisy, *op. cit.*, vol. ii, pp. 162–3.

many an English church may be seen the stone weatherings of a steep roof that gave place, in the fifteenth or sixteenth century, to one of lower pitch. Up to the end of the thirteenth century the usual pitch for an English church-roof was from 45 deg. to 50 deg., but there are many Gothic roofs in the country far steeper than this, and in Prussia may be seen gables with a slope of 70 deg.

The chief problem for the medieval builders was the dripping of water from the eaves of their roofs. At any time this tended to damage the foundations, and also the lower parts of the walls, if these were of soft stone. Bond mentions a flint-built church from the roof of which water dripped for five hundred years without ill effects. In Italy the practice was general; but there were additional reasons for endeavouring to find an alternative method. A loose slate or tile falling from a high roof is not a pleasant thing to meet, even in Italian sunshine; nor is it easy to fix ladders to a projecting eaves without a parapet, when repairs become necessary. Hence the evolution of the parapet-gutter, drained at frequent intervals by spouts or gargoyles. Figs. 179 and 180 show the progressive evolution of the gargoyle, which at first ran direct from the line of the gutter, then discharged from a channel along the axis of the buttress, and finally developed into twin channels and spouts, one on each side of the buttress. Figs. 178 and 182 are sections of typical parapet-gutters. The parapet is usually projected in front of the wall-face, following the example of the Romanesque corbel-table under a projecting eaves. But the gargoyle had its disadvantages when discharging water from the lofty roof of the nave or choir of a church on to the aisle

roof far below. Hence the adoption of such an expedient as in Fig. 181, where the water is carried over the back of a flying-buttress.[1] In buildings of the Early Italian Renaissance, before the use of a balustrade became



general, the water was allowed to drip from overhanging tiles on to the pavement below, as at the Cancelleria and Farnese palaces in Rome. In France gutters were used in the Middle Ages (from the thirteenth century

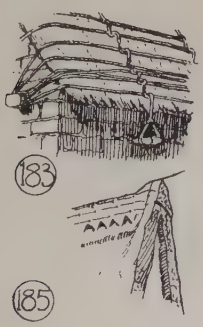
[1] On Gothic roof-drainage, see Choisy, *op. cit.*, vol. ii, pp. 372–3; and Bond, *Gothic Architecture in England*, pp. 389–400.

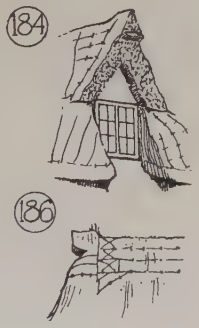
onwards), but only occasionally in Renaissance buildings. Up to the time when the Place des Vosges was laid out in Paris (*c.* 1680), gutters are seldom found on roofs of mansard or span type.[1]

The traditional roofing materials of this country are thatch, shingles, stone slates, lead, tiles, and slates proper. Lead is dealt with in Chapter X, and thin slates are only traditional in certain localities. Thatch is the oldest of these, and 'thack' originally implied any form of roofing, as it still does in parts of Yorkshire. Its use is vetoed by most bylaws, it is almost an obsolete material which few men still know how to handle, and it was forbidden in London in 1212 on account of its inflammable nature, though shingles were then permitted, Yet even to-day it is being used on some of the cottages erected under the Government Housing programme, but in such cases chimney-stacks of extra height are required as a precaution against fire. The material is either uncultivated grass (such as true reed), cultivated grass (such as rye, wheat, barley, or oats), heather, heath, furze, or sedge. Straw should be unthreshed (hence unbruised), the ears should be reaped with a sickle, and the tall stubble remaining should be mowed and then wetted before use. Heather or heath, as used in the north and in Sussex, makes excellent thatch. It is laid with the roots pointing upwards. Autumn is the best season for thatching. Starting from the eaves, which usually have a projection of 18 in. or so, the thatcher lays his bundles of straw or other material from left to right, and secures them by one of the four

[1] On drainage of French Renaissance roofs, see Choisy, *op. cit.*, vol. ii, pp. 705, 711, 742.

following methods, according to locality: (i) by plaited bands of straw about every 4 ft. in the slope of the roof, the lowest band close to the wall-plate, and all the bands laced round the spars or rafters; (ii) by rods or 'ledgers' laid horizontally *through* the bundles of thatch and secured at each end to rafters, these ledgers being generally out of sight till the thatch perishes, but sometimes arranged in patterns, and often held down by clips of hazel known as 'broaches'; (iii) by





'broaches' or 'ledgers' pegged into a layer of turf resting on the framework of the roof; and (iv) by a network of straw ropes covering the whole roof and held down at the eaves by heavy stones, as shown in Fig. 183, illustrating an example from the Isle of Man. This is the most elementary and probably the oldest form of thatching, now hardly found except in Lewis, though still used elsewhere for haystacks. Various methods of finishing the eaves and ridge are still adopted in different districts (Figs. 184 to 186). The roof when laid is 'batted' to give a smooth surface, and frequently

limed to keep away birds ; wire-netting is used nowadays for the same purpose.[1] In a recent article in the *Builder*, Mr. M. Paige Wood writes of the Sussex thatchers :

'The dwindling fraternity is a small and closely-knit one, for the craft, where it is still followed, seems to be the peculiar heritage of certain families in which it has been handed down from father to son for generations. In East Sussex the thatcher is frequently a charcoal burner as well, as were his forefathers long ago, when the iron foundries of the Weald kept them busy in the Sussex woodlands. In the hop-growing districts, there is still some demand for charcoal for the kilns, and with these two age-old crafts at his command a man can find constant employment even to-day, for the number of his competitors lessens year by year.'[2]

Shingles are wooden tiles, generally of cleft oak, about 12 in. by 6 in. or 8 in., pinned at one end to hang on a lath, and bedded on moss. They were largely used in those districts of England where wood was plentiful and stone slates scarce, even for buildings of importance (e. g. Salisbury Cathedral), but gave place to tiles about the fourteenth century, when it was realized that they were not very permanent. Now one seldom sees them except on remote churches in South-eastern England. But they have been used continuously in America since the English occupation, and are now sawn in 16 in. lengths and in random widths.

Stone slates have been used from Roman times in this country, and up to a century ago were the traditional roofing material in the north of England, the

[1] For a full account of thatching methods, see Innocent, *Development of English Building Construction*, pp. 189–215.

[2] The *Builder*, 28 October 1921.

Cotswolds, Dorset and the neighbouring counties, West Sussex and Surrey, and other large districts. In Yorkshire, slates were split in quarries close to the buildings in course of erection. Their thickness was 1 in. or more, and they were laid to a pitch of 35 to 40 deg. in diminishing courses from the eaves (where they often measured about 2 ft. square) to the ridge (where they might be only 8 in. square). They had a lap of 3 in. or 4 in. (three slates thick), and were hung (with small pegs or pins of oak driven into holes in the slates and projecting from the underside only) to oak laths

187

188

or battens nailed to the rafters. They were often bedded on moss, the trade of the 'mosser' being a recognized calling. Sometimes the row of pins on the lath was bedded in mortar. The ridge was a plain saddleback stone, somewhat like the example in Fig. 187, but worked by hand out of the solid. It was difficult to form 'swept' valleys on account of the large size of the stone slates, so generally the courses were trimmed to the sides of a V-shaped stone valley, though lead is occasionally found. Hips were practically unknown till the end of the eighteenth century, when they were made of sawn stone like the ridges. It is unnecessary to add that these roofs were enormously heavy.

The 'Cotswold' slates came principally from Colleyweston and Easton in Northamptonshire and from several quarries in Gloucestershire, the former being larger as a rule. Both varieties are very durable if properly seasoned. They were laid much like the Yorkshire slates, but to an average pitch of 55 deg., in diminishing courses, and with swept valleys. Lead was never used, and buildings were so designed as to obviate the necessity for lead gutters. Nor were eaves gutters used. Stone ridges (as in Fig. 187) were sawn out of a solid block about 9 in. wide and 3 ft. long, a series of V-shaped cuts being made, as shown in Fig. 188.

The stone slates from Horsham in Sussex were laid in diminishing courses to an average pitch of about 45 deg.

Up to about a century ago neither Welsh nor Westmoreland slates were exported to other parts of England, and where used locally they were small and thick. Old Welsh slates of this type are to be seen on some of the Cambridge colleges. Though slate was known to be a good roofing material in the seventeenth century, it was not until the cheapening of transport came when canals were opened that the whole country was flooded with Welsh slates. Then improved methods led to mechanical perfection, and the common thin Welsh slate displaced the older, rougher, and far more beautiful materials that had gone before. In France slate has always been the traditional material for roofing, often used in polychrome patterns. Figs. 188A and 188B are reproduced from sketches of my own, made recently in Blois. They show the decorative effect produced by the use of plain and ornamental slates, of somewhat small

size, hung vertically on timber framing; just as tiles were hung on timber gables in England.

Undoubtedly their rapid adoption in districts where stone slates had hitherto been used was due to the great economy that could be effected in timber thereby. At first they were known as 'blue' slates as opposed to the 'grey' stone slates. The nomenclature of slates according to their sizes even to-day is extraordinary, and among all the anachronisms and stupidities connected with the terminology of modern building there is nothing to compare with 'Duchesses', 'Rags', and 'Large Ladies'. But Mr. Innocent quotes still more ridiculous names applied to slates in earlier days.[1] Except for the comic relief provided by this fact, the slater's craft is one in which there is nothing very attractive to be found to-day, and one has to reconcile oneself to the inevitability of the Welsh slate.

Plain tiles are popularly supposed to be 'old-fashioned' roofing, but nevertheless it was necessary to import both tiles and tilers into this country during the early Middle Ages. In 1477 the size of tiles was defined by statute as $10\frac{1}{2}$ in. by $6\frac{1}{4}$ in. by $\frac{5}{8}$ in. (dimensions nearly preserved to this day), and from that time onwards they were popular in many districts, notably East Anglia. In South-eastern England, where tiles were largely used, scalloped and 'fish-tailed' varieties were introduced for roofs and for wall-hanging (Figs. 189 to 192). Ridges were formed of half-round tiles, hips of saddle-back tiles and often furnished with gablets. The workmanship of tiles was rough, and it is the combination of hand-made tiles, rough laths, and sagging

[1] Innocent, *op. cit.*, p. 178.

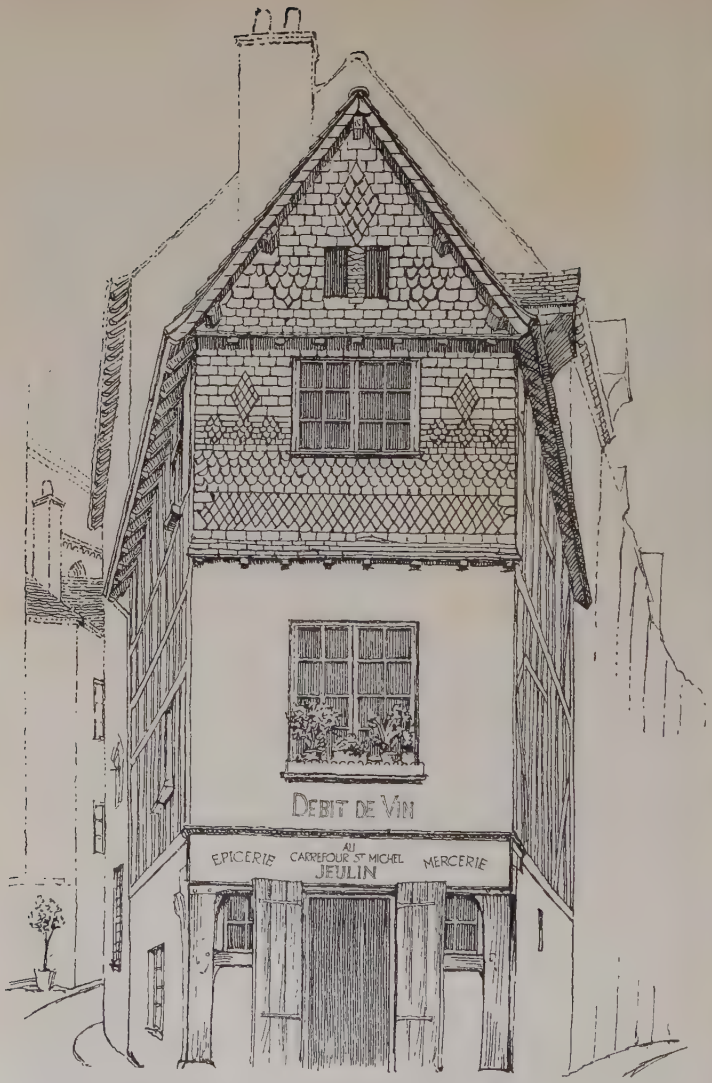


Fig. 188A. Timber-framed house hung with slates, Blois
(From a sketch by the author, 1924)

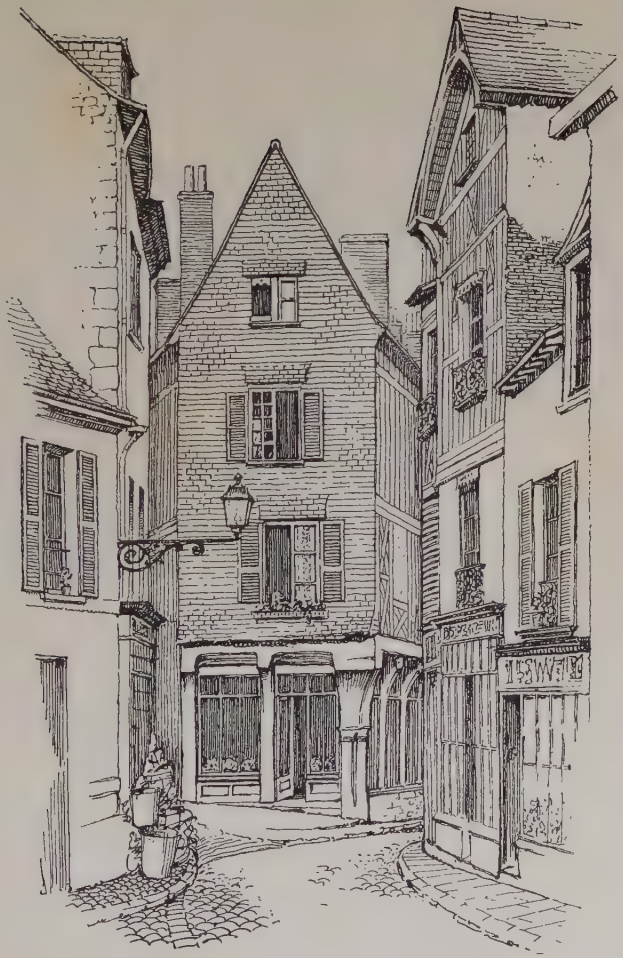


Fig. 188B. Timber-framed house hung with slates, Blois
(From a sketch by the author, 1924)

timbers that gives old roofs their variety and charm. But there are houses built in this twentieth century where, by means of cunning artifices, infinite patience, and great expense, a new roof has been made to assume the appearance of an old one. Old tiles have been stripped from some ancient barn, moss and lichen have been carefully preserved, and finally the very timbers have been shaped to produce the droop of age. The perpetrator of such a masterpiece may flatter himself that he has produced the authentic appearance of the Middle Ages, but he has altogether lost the spirit that inspired the craftsmen of the past.

Pantiles seem to have been imported at first from Holland, and an Act of 1722 fixed their minimum dimensions as 13½ in. by 9½ in. by ½ in. It is a question whether their form is suitable for our rainy climate, and the restriction of their general use to farm buildings and sheds is an evidence of British common sense.

Once again we may refer to the worthy Moxon,[1] who has something to say of tiles and of tiling as it was practised in the days of Wren. He classifies the various kinds of tiles as follows :

(a) ' *Plain Tiles* being made of a strong sort of earth like *Clay* ; and are, or should be, ten Inches and a half in length, in breadth six Inches and a Quarter, and in thickness three quarters of an Inch.'

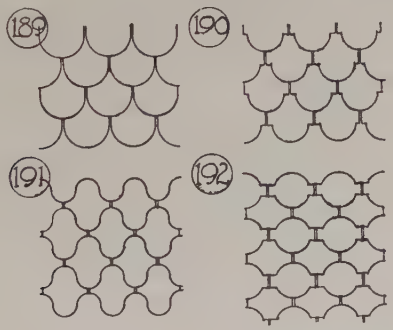
(b) ' . . . *Gutter or Hip Tiles*, which are used sometimes for *Vallies and Hips* of *Rooffs*, altho' here at *London*, the *Vallies* are commonly tiled with *Plain Tiles*, and the *Hips* with *Ridge*, or (some call them) *Roof Toiles* : These *Gutter Tiles* are in length ten Inches and a half, with a convenient breadth and thickness accord-

[1] Moxon, *Mechanick Exercises.*

ingly, and are made Circular or hollow, and wider at one end than at the other.'

(c) '. . . *Ridge* or *Roof Tiles*, being in length thirteen Inches, and made Circular breadthways like an half cylinder, whose Diameter is about ten Inches, or more, and about half an Inch and half a quarter in thickness: These are laid upon the upper parr, or ridge of the Roof, and also on the Hips.'

(d) '. . . *Pan-Tiles*, being about thirteen inches long, with a Nob or Button to hang on the Laths, and are



hollow or circular breadthways, being eight Inches in breadth, and about half an Inch in thickness, or somewhat more. The best sort of these are brought from *Holland* into *England*, and are called *Flemish Pan-Tiles*, we having such Tiles made here in *England*, but not so good: Which *Flemish Tiles* are sometimes glazed, and are of a Lead, or Blewish colour, and being glazed they are very durable and handsom.'

He says that laths—or, as we should call them, 'battens'—are made of 'heart of Oak' for outside tiling and of fir for pan-tiling. The usual lengths of laths are 4 ft. or 5 ft., but they vary; the breadth is 1½ in. or 2 in.; the thickness ¼ in. or more; but fir laths for

pan-tiling are about 10 ft. long by 1½ in. by ½ in. or more thick. For plain tiling 'reparation' or lath nails are used, and 'fourpenny' or 'sixpenny' nails for pan-tiling.

Tile-pins are either of oak or of fir—'which they drive into holes that are made in the Plain Tiles to hang them upon their Lathing'. The following is his list of tilers' tools:

(1) 'A *Lathing Hammer*, to nail on the Laths withal, with two *Gauge Stroaks* (for Lathing for Tyling) cut upon the handle of it, one at 7 Inches from the head, and the other at 7 Inches and a half; some indeed Lath at 8 Inches, but that is too wide, occasioning Rainings in.'

(2) 'A *Lathing Staff* of *Iron*, in the form of a Cross, to stay the cross Laths while they are nailed to the long Laths, and also to clench the Nails.'

(3) 'A *Tyling Trowel*, to take up the Morter and lay it on the Tiles, it being longer and narrower than a *Brick-Trowel*, altho' for a shift many Times they use a *Brick-Trowel* to Tyle withal, when they have not a *Tyling-Trowel*.'

(4) 'A Bosse, made of Wood, with an Iron Hook, to hang on the Laths, or on a Ladder, in which the Labourer puts the Morter which the Tyler uses.'

(5) 'A Striker, which is only a piece of Lath about 10 Inches long, with which they strike, or cut off the Morter at the britches of the Tiles.'

(6) 'A Broome, to sweep the Tyling after 'tis strooke.'

IX

PLASTERWORK

In the last chapter it was noted that, up to the nineteenth century, iron was hardly ever employed structurally in building. Of plaster it may be said that it was never structurally used. It either formed a smooth surface on internal walls, and thus provided a ground on which ornament might be painted or modelled, or else it was applied to the exterior of a building, in order to increase the resistance to the weather. Occasionally, as in the 'parged' houses of East Anglia, it served both a decorative and a utilitarian purpose. According to its composition and its surface, it is known as 'plaster', 'stucco', 'rough cast', and by a variety of other names.

The plaster used by the Ancient Egyptians was made of burnt gypsum, and was thus the same material as our so-called 'plaster of Paris'. It was applied to stone walls to fill up holes and cracks, and was then coloured to match the stone. In some of the rock-tombs where this was done the plaster has survived where the adjoining stone face has decayed. Brick walls had a hard facing of plaster $\frac{1}{10}$ to $\frac{1}{16}$ in. thick. A smooth surface was thus obtained for the beautiful paintings that tell us so much of Egyptian life. By the period of the eighteenth dynasty the work had begun to deteriorate in quality, and, whereas the plaster facing was sometimes no more than a coat of whitewash, in other cases

it was 2 in. or 3 in. thick to fill up jagged holes in the masonry. Plaster or stucco was also used on wooden partitions, laid on a canvas base or on reeds laced together with cords to form a primitive system of lathing. The evidence of remains proves that such plaster closely resembled our modern 'three-coat work', being about $\frac{3}{4}$ in. thick and mixed with hair. Plaster was used with canvas in modelling the mask-portraits on the lids of mummy-cases. On walls and partitions modelling in very low relief was frequently done, the brilliant sunshine of Egypt always giving full value to the finest lines. Externally, plaster or stucco formed a preservative coat to brick walls. Even floors were sometimes floated with the same material, e. g. at Tel el-Amarna, where it is laid on brick. According to Millar:

'. . . The first coat is of rough lime stucco about 1 in. thick, and the finishing coat of well-haired plaster about $\frac{1}{8}$ in. thick, very smooth and fine, and showing evidence of trowelling, the setting-out lines for the painting being formed by a struck cord before the surface was set, and the painting done on fresco.' [1]

This remarkable floor is in a royal palace dating from *c.* 1400 B. C., and is elaborately painted. (See Plate I in Millar's *Plastering*.) Even in those remote days the plasterer's tools were almost identical in form with those now used, and Fig. 192A shows a hand-float of the eighteenth dynasty from the British Museum.[2]

In Assyria there appears to have been little, if any, plaster used, the walls of the palaces at Nineveh being

[1] Millar, *Plastering*, pp. 1–2.

[2] On Egyptian plastering, see Millar, *op. cit.*, pp. 1–2; Petrie, *Arts and Crafts of Ancient Egypt*, pp. 142–4; Simpson, *History of Architectural Development*, vol. i, pp. 21–2, 30.

lined with glazed tiles or with slabs of gypsum or alabaster about 1 ft. thick.[1] But stucco was largely employed during the later (Sassanian) period both internally and externally. At Mycenae and Knossos plaster was used by the primitive Greeks and the Cretans respectively. The palace at the latter site provides examples of limestone walls with a thin coating

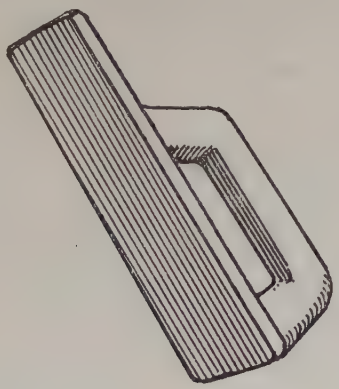


FIG. 192A.

of plaster, and the ceilings appear to have been made with reeds daubed with plaster, as in many a Cretan cottage to-day.[2]

In Chapter VI it was mentioned that the Romans grained cheap woodwork in imitation of more expensive figured varieties. This shocking instance of early hypocrisy might seem to be matched by the Greek use of stucco on their limestone temples to produce an effect

[1] Layard, *Nineveh*, p. 343.

[2] Bankart, *Art of the Plasterer*, pp. 4–5; Hawes, *Crete, the Forerunner of Greece*, p. 30.

of marble, but, in fairness to a race that placed so high a value on beauty, one must assume that this was done only to allow of mouldings and ornament being rendered with the delicacy that the Greeks loved. This plaster was really stucco, made with marble-dust, applied in a very thin coat, and frequently decorated with painting. Remains have been found at Corinth, Aegina, Paestum, and in the great temples in Sicily.[1]

The same material is found in Etruscan tombs in Italy, some of which are as old as the seventh century B.C. Here it is $\frac{1}{12}$ to $\frac{1}{8}$ in. thick (at Corneto), but has peeled off the tufa walls in many places, owing to damp. In Roman *stucco duro* the craft of the plasterer reached perhaps its highest point. Of the technique of this work Vitruvius has much to tell us, and stucco is allotted more space in his famous treatise than any other building material. He devotes two chapters [2] to the preparation of the ingredients, lime and marble. He writes that lime must be thoroughly slaked before use, in order to get rid of lumps that have not been properly burned in the kiln. If any of the lime escape slaking, it is liable to blister afterwards, thus spoiling the smooth polished face of the stucco. He then gives a simple test to determine the efficacy of the slaking process. If a hoe be put into the mortar bed and on being withdrawn the lime sticks to it like glue, the slaking has been satisfactory. If, on the other hand, it is dry and clean, the lime must be weak and thirsty; and if it sticks to the hoe in bits, then the lime is not properly tempered.

[1] On Greek plaster, see Simpson, *op. cit.*, pp. 85–6; Bankart, *op. cit.*, pp. 4–5; and Viollet-le-Duc, *Dictionnaire*, s.v. 'enduit'.

[2] Vitruvius, VII. ii and vi.

Speaking of marble, he says that certain kinds 'contain transparent grains like salt, and this kind when crushed and ground is extremely serviceable in stucco work'.

For the timber firring or cradling pieces of curved plaster vaults he recommends cypress, 'as fir is soon spoiled by decay and by age'. He adds that common oak 'warps, and causes cracks in work in which it is used'. In place of lathing such as we employ, he describes a method by which reeds, 'previously pounded flat,' are bound with cord made of Spanish broom to the firring pieces in such a way as to give the desired curve.

'Immediately above the vaulting spread some mortar made of lime and sand, to check any drops that may fall from the joists or from the roof. . . . Having thus set the vaultings in their places and interwoven them, apply the rendering coat to their lower surface; then lay on the sand mortar, and afterwards polish it off with the powdered marble.'[1]

Of mouldings he says:

'Gypsum should not be used in their composition, but powdered marble should be laid on uniformly, lest gypsum, by setting too quickly, should keep the work from drying uniformly. . . . Having finished the mouldings, apply a very rough rendering coat to the walls, and afterwards, when the rendering coat is fairly dry, spread upon it the layers of sand mortar, exactly adjusted in length to rule and line, in height to the plummet, and at the angles to the square. The stucco will thus present a faultless appearance for paintings. When it gets fairly dry, spread on a second coat and then a third. The better the foundation of sand mortar that is laid on, the stronger and more durable will be the stucco.

[1] *Ibid.*, VII. iii. 1 and 2.

'When not less than three coats of sand mortar, besides the rendering coat, have been laid on, then we must make the mixture for the layers of powdered marble. . . . After this powdered marble has been laid on and gets dry, lay on a medium second coat. When that has been applied and well rubbed down, spread on a finer coat. The walls, being thus rendered solid by three coats of sand mortar and as many of marble, cannot possibly be liable to cracks or to any other defect. And further, such walls, owing to the solid foundation given by thorough working with polishing instruments, and the smoothness of it, due to the hard and dazzling white marble, will bring out in brilliant splendour the colours that are laid on at the same time as the polishing. These colours, when they are carefully laid on stucco still wet, do not fade but are permanent. This is because the lime, having had its moisture burnt out in the kiln, becomes porous and loses its strength, and its dryness makes it take up anything that may come in contact with it.'[1]

Vitruvius also gives suggestions for dealing with damp walls, either by means of a dado 3 ft. high, of mortar mixed with burnt brick instead of with sand, or by means of a cavity wall, with the cavity ventilated at the top and drained at the bottom below the level of the adjoining floor, or by other methods.[2] Lastly he describes the construction of a dry floor for dining-rooms, with a foundation of what we should call 'hard-core' 2 ft. deep, then 6 in. of 'mortar' made of gravel, sand, and ashes, and finally a floated surface 'smoothed off with whetstone', giving a polished black appearance.

'Hence, at dinner-parties, whatever is poured out of the cups, or spirted from the mouth, no sooner falls than it dries up, and the servants who wait there do

[1] Vitruvius, VII. iii. 3–7. [2] *Ibid.*, VII. iv. 1.

not catch cold from that kind of floor, although they may go barefoot.' [1]

These extracts from Vitruvius are justified by the importance of Roman stucco. Its excellence was such that its polished surface has been compared to a mirror, and jewellers used stucco for their most delicate models. Its thickness varied greatly, being sometimes as little as $\frac{1}{16}$ in. internally, and as much as 3 in. externally. For retarding the setting, various substances were used, including fig-juice, curdled milk, lard, blood, rye dough, and white of egg. Professor Lethaby says [2] that, in Roman Britain, buildings externally were coloured dark red; adding that a convex rounded fillet (concave in one example he has seen in Rome) was used at the junction of floor and walls, also at the angles of the walls. Roman fresco-painting and modelling in stucco are equally famous, and inspired most of the plasterwork of the brothers Adam.[3]

Widespread as had been the use of stucco under the Roman Empire, the art of the plasterer was, to some extent, lost during the Dark Ages, but plaster is found in Anglo-Saxon churches in England and in Merovingian and Carlovingian churches in France, generally to mask irregularities of rubble masonry. Figs. 193 and 194 illustrate stucco details from the cloisters of the church of Germigny-des-Prés (early ninth century), the material being fine, white, and hard, and cut with a chisel while still fresh.[4]

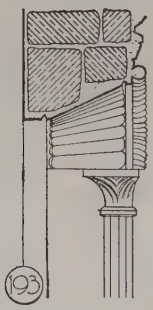
[1] *Ibid.*, VII. iv. 5.

[2] Lethaby, *Londinium.*

[3] On Roman stucco, see Simpson, *op. cit.*, vol. i, pp. 115, 123; Bankart, *op. cit.*, pp. 6–7, 12–21; Anderson and Spiers, *op. cit.*, pp. 141, 215–16, 271–2.

[4] See Viollet-le-Duc, *Dictionnaire*, s.v. 'enduit', 'stuc', and 'plâtre'.

In Gothic times plaster was used almost solely inside churches, to furnish a smooth surface for fresco-paintings on rubble walls and vaults. But at Narbonne is a small fourteenth-century rose-window in plaster, and other ornamental features in stucco are known. This reminds us that the Byzantines had employed the same material for pierced windows, cornices, and other details; while in Saracenic art stucco ornaments were freely used from the ninth-century mosque of Ibn Tulun at Cairo



193

194

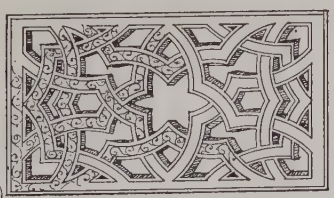
onwards, those of the Alhambra being specially famous. The material was eminently suited to the fine lines required in Eastern sunshine, and appears to great advantage in the pierced windows illustrated in Figs. 195 and 196.[1]

During the early stages of the Renaissance in Italy, attention was focussed on the *stucco duro* of the Romans, and what had been a lost art was suddenly resuscitated, probably about 1488. Donatello mixed pounded brick and glue in his stucco, the result closely resembling

[1] On Saracenic plasterwork, see my *Muhammadan Architecture, &c.*, pp. 200–1.

terra-cotta. It was about forty years later that the new Italian fashion spread to England. All through the sixteenth century foreign craftsmen were busy in this country, but gradually the English plasterer grafted their innovations on to his own traditions. There are

(195)



(196)

two remarkable early ceilings at Hampton Court, where the enterprise of Wolsey introduced many Italian novelties. In the 'Watching Chamber' the ceiling is divided into panels by moulded wooden ribs, which are curved down here and there to form pendants. The ribs are secured to the joists above, as are various ornamental bosses of papier mâché. In 'Cardinal

Wolsey's Closet ' wooden ribs are again used, but a plain wooden boss is fixed at their intersection, with four leaves of lead springing from it. It appears that quite early in Elizabethan times cast ornaments and mouldings were introduced. Often the ribs were cast in plaster of Paris from reverse moulds, and such ' spots ' of ornament as flowers, leaves, &c., were cast, while the scrolls connecting them were modelled by hand. Mr. Bankart suggests that casting may have been done thus :

' The enrichment [was] modelled in plaster or clay, a mould being cast from the same in plaster. This mould would be soaped, varnished, or coated with some preparation to stop the suction of the plaster. A semi-liquid plaster would then be poured in, and the mould immediately applied to the ceiling and held there by a stay from the scaffolding until sufficiently set to allow of its removal, the enrichment being afterwards cleaned and touched up where needed with a small metal tool by hand.' [1]

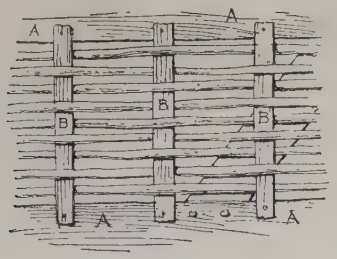
It appears that plasterers travelled from place to place with patterns of such enrichments and mouldings.[2]

We must now trace the parallel development of plastering among the country craftsmen. At the beginning of the thirteenth century a royal ordinance insisted that all London houses then covered with reed and rush were to be plastered, as a result of a serious fire in 1212. This so-called ' wattle and daub ' construction, known by many other dialect names, is illustrated in Fig. 197, and lasted up to Renaissance times. Slats or laths of cleft oak (B) were nailed to the horizontal timbers (A)

[1] Bankart, *op. cit.*, pp. 45–53.

[2] Sir T. G. Jackson, *Renaissance of Roman Architecture*, vol. ii, p. 115.

of the framing, and between these were interwoven 'wattles', hazel sticks ½ in. to 1 in. in diameter, with the bark left on. To this primitive lathing was applied a thick layer of clay, mixed with straw to toughen it. The 'daubers' worked one on each side of the wattle, throwing on the clay until the desired thickness was reached. The next development was the addition of a plastered surface on each side of the clay, the latter material being liable to expansion and contraction under the influence of the weather.



197

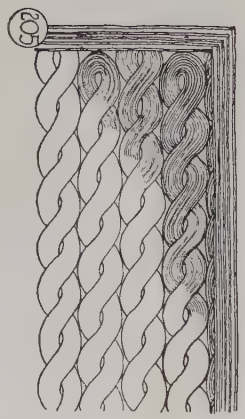
Next came the introduction of laths, which in the Middle Ages were of cleft oak or beech, classified according to their strength, as at the present day. The size of a lath was ordered to be 1 in. by ½ in. in Edward III's reign, and 5 ft. by 2 in. by ½ in. in 1528, but laths have been found as much as 4 in. wide. Often they were 'sprung' into grooves in the timber framing. Lath and plaster 'walls' were usually hollow, but were often filled in with straw or bran. Even in large houses lath and plaster ceilings only became general in the sixteenth century.

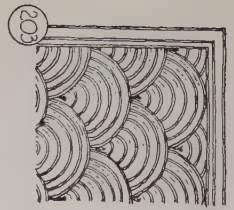
Late in that century and early in the one following,

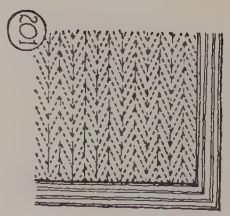
another variety of plastering displaced Italian *stucco duro* in England. This was known as 'parging', or 'pargetting', and consisted in the use of a mixture of lime, sand, and hair or chopped hay or cow-dung. This was very well washed, beaten, and stirred, and thus acquired a tough and almost leathery consistency. It is found especially in Essex and Suffolk, on timber-framed buildings. The surface of the plaster was often finished with rough-cast or 'pebble-dash' of various

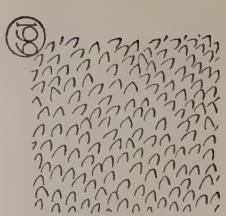
198

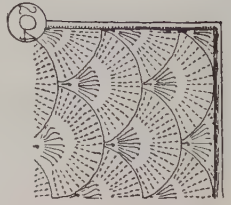
kinds, but in East Anglia numerous patterns are found which were made by means of a five-pronged comb with a handle, with a pointed stick, or (in the case of fan-patterns), with a fan of pointed sticks. Some of these patterns are illustrated in Figs. 199 to 205. Rectangular panels, with sunk strips representing styles and rails, or with the panels themselves sunk, were often used, as well as a great variety of modelled ornament, often based on classic *motifs*, though quite rustic in execution. Overhanging stories are a characteristic feature of these plastered houses in East Anglia, and Fig. 198 shows a

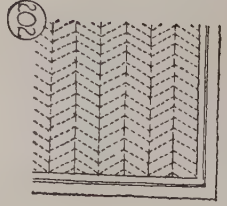

203

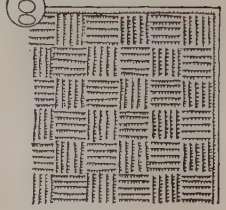

203


201


199


200


202


198

typical example from Thaxted. In half-timber construction, early examples had the plaster set back about ½ in. behind the timbering, next they became flush, and in late work the plaster was often carried right over the timbering so that the latter became invisible.[1]

A great change in plastering methods, as in all the crafts, came in the days of Inigo Jones and Wren. Hitherto modelling had been somewhat small in scale, of slight projection (except in the case of ceiling-pendants), and well suited to the nature of the material. Now came a great boldness of design, with domes, deep coves, classical cornices, coffering, and great bands of undercut fruit and flowers introduced by Grinling Gibbons. The latter ornament had stems made of lead piping and strips of lead, while wires and hickory twigs were freely used. Much of the ornament was cast in small pieces. The architect now undertook the design of the plasterwork as of all other details of the building. But it was not until the early years of the eighteenth century that plastering ceased to be a traditional craft. Then it became more and more a matter of working from 'the antique', and guilloches and modillions were turned out by the mile.

But there was a brief and brilliant revival of the *stucco duro* of the Romans under the brothers Adam at the end of the eighteenth century. Their designs may have been somewhat archaeological, but were extra-

[1] On external plastering in England, see Bankart, *op. cit.*, pp. 55–7; Oliver, *Old Houses in East Anglia*, pp. 37–9; L. Turner, in *The Arts Connected with Building*, p. 173; Innocent, *Development of English Building Construction*, pp. 137–44.

ordinarily delicate and beautiful. The material used was a composition known as 'Liardet's preparation', in which they were financially interested, but used externally it proved a failure, and involved them in heavy losses. Their ceilings were often coloured, usually light pink or green. With the invention of Portland cement over a century ago, and the stucco period of Nash, we reach modern times.

In conclusion, the invaluable Moxon's notes[1] on plasterers' materials and tools in the time of Wren may be quoted. For outside plastering he recommends laths made of heart of oak, and of fir for inside work. With regard to the mixing of the materials, he says:

'They also put *Ox* or *Cow* Hair into the *Morter* which they use for *Plastering*, being called *Lime* and *Hair*, which Hair keeps the *Morter* from Cracking or Chaping, and makes it hold or bind together. But whereas they make use of the sharpest Sand they can get, (that being best) for *Morter*, to lay Bricks and Tiles in; so they chose a fat *Loamy* or Greasy Sand for inside Plastering, by reason it sticks together, and is not so subject to fall assunder when they lay it on Seelings or Walls.'

He writes as follows 'Of the Names and Uses of Tools relating to Plastering':

'(1) A *Lathing Hammer* being the same as before in Tyling, with which the laths are nailed on with its head, and with its Edge they cut them to any length, and likewise cut off any part of a Qurter, or Joyst, that sticks further out than the rest.'

'(2) A *Laying Trowel*, to lay the Lime and Hair withall upon the Laths, it being larger than a *Brick Trowel*, and fastned its handle in a different manner from the *Brick Trowel*.'

[1] Moxon, *Mechanick Exercises*.

'(3) A *Hawke*, made of Wood about the bigness of a square Trencher, with a handle to hold it by, whereon the Lime and Hair being put, they take from it more or less as they please.'

'(4) A *Setting Trowel*, being less than the *Laying Trowel*, with which they finish the Plastering when it is almost dry, either by Trowelling and brishing it over with fair *Water*, or else by laying a thin Coat of fine stuff made of clean Lime, and mixt with Hair without any Sand, and setting it, that is to say, Trowelling and brishing it.'

'(5) A small *Pointing Trowel*, to go into sharp Angles.'

'(6) *Brishes*, of three sorts, viz. A *Stock Brish*, a *Round Brish*, and a *Pencil*. With these *Brishes*, they wet old Walls before they mend them, and also brish over their new Plastering when they set, or finish it, and moreover white and size their Plastering with them. The *Pencil* or *Drawing Tool*, is used in blacking the bottoms, or lower ports of Rooms, &c.'

'(7) *Floats*, made of Wood, with handles to them, which they sometimes use to float Seelings or Walls with, when they are minded to make their Plastering very streight and even, these *Floats* being some larger, and some lesser, than the *Laying Trowels*: Likewise they use *Floats* made to fit to Mouldings, for the finishing of several sorts of Mouldings with finishing Morter to represent Stone, such as *Cornices*, *Facias*, *Archytraves*, &c. The finishing Morter to represent Stone, should be made of the strongest Lime, and the sharpest Sand you can get, which Sand must be washed in a large Tub, very well, till no Scum or Filth arise in the Water, when you stir it about, which sometimes will require to have Water 5 or 6 times, when the Sand is somewhat foul; and it requires a greater Proportion of Sand than the ordinary Morter, because it must be extreamly beaten, which will break all the knots of *Lime*, and by that means it will require more Sand.'

'(8) *Streight Rules* of several lengths, to lay Quines

streight by, and also to try whether the Plastering be laid true and streight, by applying the Rules to their Work.'

'(9) A *Pale*, to hold *Water* or *Whitewash*, or *White* and *Size*.'

'(10) Some use a *Budget* or *Pocket* to hang by their sides, to put their *Nails* in when they *Lath*, and others Tuck and tye up their *Aprons*, and put the *Nails* therein.'

X

EXTERNAL PLUMBING

The typical plumber shares the honours at modern music-halls with the typical policeman and the typical mother-in-law. Any one of these three imaginary characters is always sure to provoke a laugh, not least the plumber—the man who invariably fails to mend a burst pipe, and as invariably has to return home for the tools he has forgotten to bring. English humour is largely based on somebody else's discomfiture, and, a burst pipe being a discomforting thing, the incident itself is full of humour. But the character of the plumber himself, as the incompetent workman, must surely have some justification in fact.

Modern plumbing appears to the man in the street as a matter of pipes and little else. The gas-fitter and the heating engineer have further curtailed the plumber's province, and nowadays his functions inside the house are restricted to water-pipes and waste-pipes only. He is known to have some minor and little-understood share in the covering of a roof, but, that being limited to a few strips of lead here and there, mostly concealed when the building is complete, he is the very last among the makers of the building whom the general public regard as a craftsman. For them his work should be hidden as far as possible, and mentioned either as a joke or as something almost indecent. Yet if one refers to the article 'Plomberie' in Viollet-le-Duc's famous *Diction-*

naire raisonné, one finds there a study of the artistic leadwork of the Middle Ages. In the old days plumbing, or leadwork, was a craft, even an art. As this chapter will prove, and as all capable architects know already, lead is not a mean material if properly handled. Like plaster, it is well suited to soft outlines in low relief, and away from the smoky and acid-laden atmosphere of industrial towns it assumes with age a silvery colour that adds to the charm of many an old church spire and garden.

But not until the Middle Ages do we find it extensively employed on buildings of which there are remains. In Ancient Egypt it was known, at any rate during the later dynasties, and small objects of lead were deposited as charms in the foundations.[1] But Sir Gardner Wilkinson states that it was sometimes used for inlaying temple doors, coffers, and furniture. It was also known to the Assyrians, probably in connexion with masonry, and Herodotus mentions a later bridge at Babylon, of stone bound together with lead and iron. Professor Lethaby has illustrated the small inscribed lead plummets, about 3 in. by 1 in., used by the Greeks, of which several are preserved in the British Museum, and also notes the employment of lead in pediment sculptures and as an inlay.[2]

The Romans used the metal freely: for covering roofs, for lining cisterns and baths, for water-pipes, and (as already noted in Chapter III) in connexion with masonry. Sheet lead was employed for roofs and gutters. The Roman bath at Bath was lined with sheets

[1] Petrie, *Arts and Crafts of Ancient Egypt*, pp. 103–4.
[2] Lethaby, *Leadwork*, p. 7.

of lead 10 ft. long, weighing 30 lb. per sq. ft. At Bath there is also a water-channel 1 ft. 9 in. by 7 in. of lead nearly 1 in. in thickness, according to Professor Lethaby.

A great deal of interesting information on Roman methods of plumbing and water-supply has been collected by Dr. Middleton.[1] Water was brought to the chief cities in aqueducts, and distributed from a *castellum aquarum* or reservoir, but was first purified by being carried through filtering tanks and settling tanks before passing into the mains, besides preliminary purification before it entered the aqueduct. Only the largest houses had storage cisterns, as the municipal water-supply was constant and reliable. In spite of Vitruvius' warning [2] about the danger of lead-poisoning, lead was generally used for both mains and branches, and the coating of lime or 'fur' that soon covered the interior of the pipes seems to have been regarded as a sufficient safeguard against poisoning. Pipes of earthenware, stone, and wood (elm or fir), are also mentioned by Latin writers, and examples of the first two have been found, some of the stone pipes having a diameter as much as 2 ft.

The lead pipes were made by rolling thick sheets of cast lead round a wooden core, in 10 ft. lengths, and the edges were then soldered together with an alloy of tin and lead (Fig. 205A, II). The illustration shows the curious section of the pipe, and the weakness of the joint to resist any considerable pressure. It appears from Vitruvius and from the examples found that these pipes were made in standard sizes, each with its distinctive name. Some of the pipes with a diameter of 5 in. have

[1] J. H. Middleton, *The Remains of Ancient Rome*, ii. 314–35.
[2] Vitruvius, VIII. vi. 10.

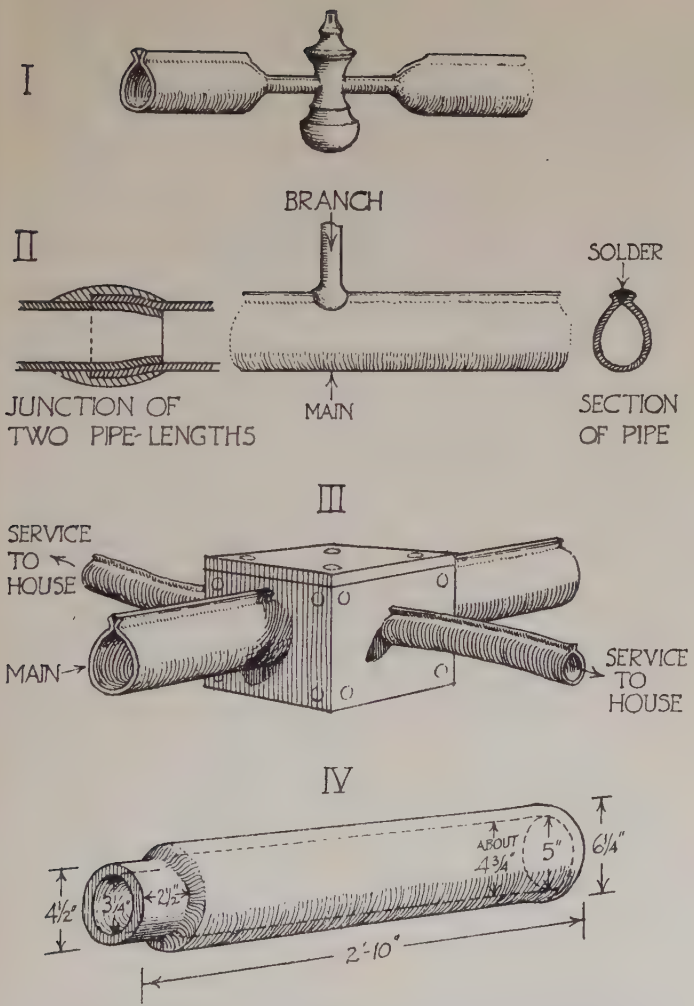


Fig. 205A. Roman Water-Pipes. I, Stopcock (*epistomium*), after Middleton; II, Various pipe-joints, after Middleton; III, Junction box in roadway, after Middleton; IV, Earthenware down-pipe (*tubulus*) from villa at Folkestone. Author's own sketch.

a weight of 20 lb. per sq. ft., and hence a thickness of about $\frac{1}{3}$ in.

The lead was cast in sheets about 10 ft. long and probably rather less in width, on a smooth bed of sand, and was then cut up into strips to suit the diameter of the pipe to be made. On this bed of sand were recessed inscriptions in reverse from wooden or marble patterns, recording the names of the reigning emperor, the owner of the house, the plumber, and the water-supply officials, or some of these facts ; hence much useful information has been gathered from lead water-pipes, though most of them have been melted down long ago.

The 10 ft. lengths of pipe were joined together as shown on Fig. 205A, II, the end of one pipe being let into the other, and solder being then fused round. The junction of the separate house branches to the mains were made either as shown in Fig. 205A, II, or better as in III, by means of a cubical lead junction-box in the roadway.

Well made stopcocks of bronze were soldered to the lead pipes where necessary, to enable repairs to be executed (Fig. 205A, I). There is a very large one from Pompeii in the Museum at Naples. Water-taps were commonly made in the form of an animal's head. At the end of a pipe where it discharged over a cistern, tank, or fountain, a perforated lead strainer was often fixed. The ornamental fountain frequently found in the centre of the courtyard of a house was supplied with water which generally spouted from a fish or shell held in the hand of a bronze figure, the lead pipe being carried up inside the hollow bronze statue so that it was not visible.

Rain-water pipes or 'down-pipes' were commonly

made of earthenware with socket joints, and were usually embedded in the concrete mass of the walls. They carried the water from the house roofs to the street sewer. Fig. 205A, IV, shows one of these earthenware down-pipes (*tubuli*) from the recently discovered Roman villa at Folkestone. Sometimes the rain-water pipes were fixed externally on the walls, as in modern practice. Then they were invariably of lead and were called *fistulae*. In Rome, as in Athens even earlier, it was forbidden by law to allow water to drip from eaves-gutters into the street below.

Examples of Roman pipes used in England are to be seen in the Guildhall and other museums, and an example from Chester is described and illustrated by Mr. S. B. Bennett.[1]

Much lead was obtained from the north of England and from Wales, not only in Roman days but long before, when the Phoenicians voyaged to our shores in search of tin. In remote places in the Yorkshire dales may still be seen disused lead workings, now rendered unprofitable by improvements in modern transport and by cheap labour abroad.

Lead was largely used in Byzantine architecture for covering domes and for other purposes. Constantine's basilica of the Holy Sepulchre at Jerusalem was covered with sheet lead.[2] Examples of Romanesque lead-work of certain date are not very numerous, but confirm the definite testimony of records as to the extensive use of the metal for architectural purposes. In England are preserved some thirty lead fonts of various dates,

[1] S. B. Bennett, *A Manual of Technical Plumbing*, p. 73.

[2] Lethaby, *Leadwork*, p. 36.

among which twelve at least are Norman. In these fonts Romanesque leadwork displays a high level of design and craftsmanship; they are unimportant, however, from the point of view of construction. But many church roofs were of lead in Saxon times, and lead was largely exported to the Continent in those days. York Minster is said to have been roofed in lead about 669.[1] Bede relates of the church at Lindisfarne that, in 638 the bishop 'took off the thatch and covered it, both walls and roof, with lead'. In France at the same period lead was largely used externally. Viollet-le-Duc, in his article 'Plomberie', writes: 'Under the Merovingian kings, entire edifices—churches and palaces—were covered with lead. St. Eloi is said to have so covered the church of St. Paul des Champs with sheets of lead artistically wrought.' The choir of Canterbury (1093–1130) was covered with lead, as were the choir-aisles in 1184.

From the thirteenth century to near the end of the sixteenth leadwork was largely employed for the roofing of churches, but the ornamental pipes, pipe-heads, and cisterns so characteristic of the Tudor and Stuart periods were little used, if at all. The Gothic epoch in France produced a great deal of ornamental leadwork in cresting crockets, and finials; but, from the time when the English craftsmen designed the Norman fonts already mentioned to the date of the ornamental pipe-heads at Haddon Hall, English leadwork was almost entirely confined to plain sheets laid on roofs and to utilitarian gutters, that is to 'plumbing', even in our limited use of the word. Some-

[1] Bond, *Gothic Architecture in England*, p. 389.

thing has already been said of gargoyles and gutters in Chapter VIII, and, as a rule, lead was carried along the tops of gargoyles, dressed down into a channel thereon, and carried over the end. But in 1241 Henry III wrote to the Keeper of the Works at the Tower of London:

'We command you to . . . cause all the leaden gutters of the great tower through which rain water should fall from the summit of the said tower to be carried down to the ground, so that the walls of the said tower, which has been newly whitewashed, may be in no wise injured by the dropping of rain water nor be easily weakened.'[1]

At Kettering Church is a rare example of a lead down-pipe, illustrated by Bond,[2] who mentions others at King's College Chapel, Cambridge; but gives it as his opinion that the medieval builders avoided the use of down-pipes because these are liable to become choked, and preferred the primitive arrangement of gargoyles where all the drainage was open and visible.

Professor Lethaby is of opinion that lead was used in roofing simply for aesthetic reasons, and points out that 'the creeping of lead on steep surfaces, the many burnings, and the great expense in large churches which would take literally acres of lead, made maintenance a burden'.[3] From a twelfth-century document it appears that a certain carpenter had to do plumbers' work in his own district, indicating that the craft of the plumber was not then definitely recognized,[4] but in the fourteenth century the Plumbers' Company was established in London.

[1] Weaver, *Leadwork*, p. 24.
[2] Bond, *op. cit.*, p. 401.
[3] Lethaby, *op. cit.*, pp. 18–19.
[4] Innocent, *op. cit.*, p. 147.

The lead used in the Middle Ages was cast, not 'milled' like modern lead. The former is generally very thick, weighing as much as 12 or 13 lb. per sq. ft. The casting was done on a bed of smooth sand specially prepared for each sheet. The process has been well described by Mr. F. W. Troup,[1] and Fig. 205B (from an old print) shows the apparatus required. The casting-frame resembled a long table in appearance, with a 4 in. rail all round. On this table was laid sand about 2½ in. thick, which had to be kept damp. When, in the sixteenth century, ornamental features were used on leadwork, models of them were pressed into the sand-bed, just as was done for the Sussex iron firebacks (see Chapter VII). Molten lead was then poured over the bed, and superfluous metal removed with a 'strike'. This casting was usually done on the site. Such a method produced a pure and natural sheet of lead, but, in order to avoid flaws caused by steam rising from the damp sand below, it had to be made unnecessarily thick and therefore very heavy. The comparative merits of cast and milled lead have long been wrangled over by architects, but the prejudice that still lingers against milled lead is gradually giving way to a common-sense view of modern needs.

Viollet-le-Duc[2] points out that medieval lead is seldom eaten away by the acids from the sap in the boarding beneath, as the latter was always thoroughly seasoned. He also remarks on the intimate connexion between carpentry and leadwork. Old lead contained much silver and arsenic, hence the beautiful white *patina* that appears on it with age.

[1] Troup, in *Arts Connected with Building*, pp. 191–9.
[2] Viollet-le-Duc, *Dictionnaire*, s.v. 'Plomberie', p. 210.

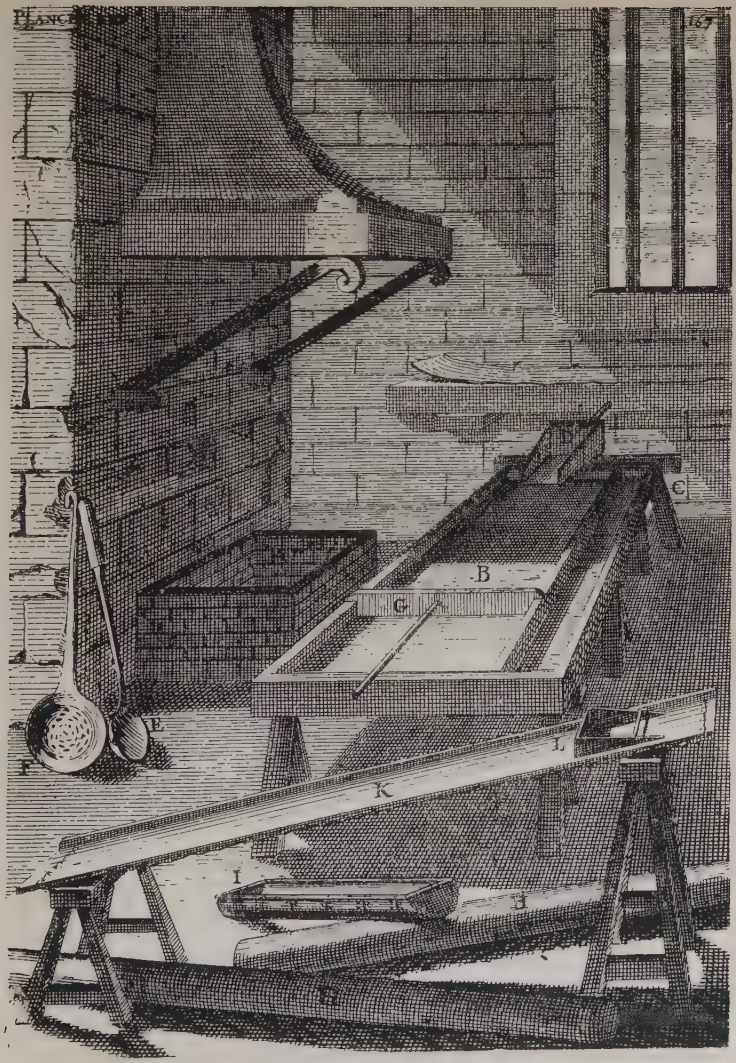
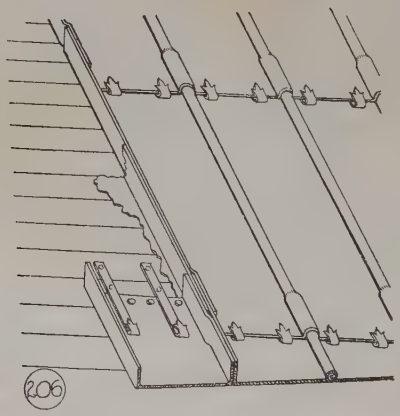


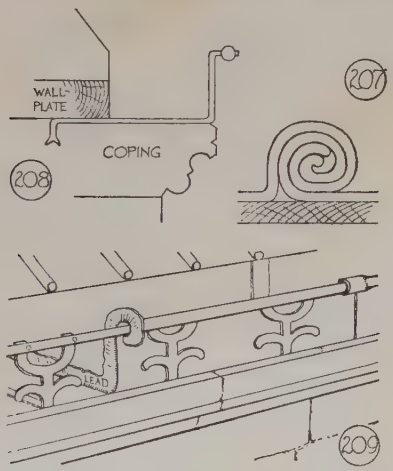
Fig. 205B. A plumber's workshop, seventeenth century (From Félibien's *Principes de l'Architecture*, 1676).

The object to be attained in laying lead is so to secure it that it is free to expand and contract, yet firm enough to throw no undue weight on the supporting rafters and boarding, thus avoiding sagging of the timbers and the resultant water-holding depressions in the lead sheet. Figs. 206 and 207 (adapted from Viollet-le-Duc) show how this was done at Chartres Cathedral in the thirteenth



century. The lead was about $\frac{1}{6}$ in. thick, in sheets not more than 2 ft. wide and 8 ft. 4 in. long. These were nailed at the top, with iron nails having very large heads, to oak boarding. The side of each sheet was so rolled up with the edge of the sheet adjoining as to form rolls of rather more than $1\frac{1}{2}$ in. diameter (Fig. 207). The bottom edge was secured by two iron clips to prevent the wind from blowing it up. The tails of the clips were nailed to the boarding. All this work was sound when examined in 1835. At Canterbury the sheets were 2 ft. wide and of 12 lb. lead.

Another requirement for plumbing on roofs is that every piece of lead can be as easily removed or replaced as is a tile or slate. In Gothic work this was contrived not only for plain sheets and for gutters, but also for the elaborate lead ornaments that were used so largely in France and that Viollet-le-Duc has described.[1] The medieval craftsman showed himself thoroughly practical

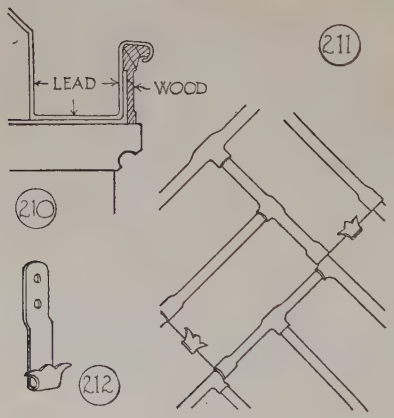


in all plumbing details; thus, he provided small outlets in the leadwork to ventilate the roof-timbers, and where he had to put a nail on an exposed surface he was careful to protect it from the weather by means of a small lead flap.

In the chapter on 'Roof Coverings' (Chapter VIII) the development of the parapet gutter was briefly described. Figs. 208 and 209 illustrate a type of eaves

[1] Viollet-le-Duc, *op. cit.*, pp. 214–18.

gutter often found in France. Here the lead strips forming the gutter, each about 4 ft. in length, are dressed over an iron rod, supported on iron brackets carried under the gutter, and caulked into the coping-stone under the wall-plate. The gutter is lapped, with a drip at each joint and a gargoyle at about every other joint. Fig. 210 [1] shows how a wooden fascia was used

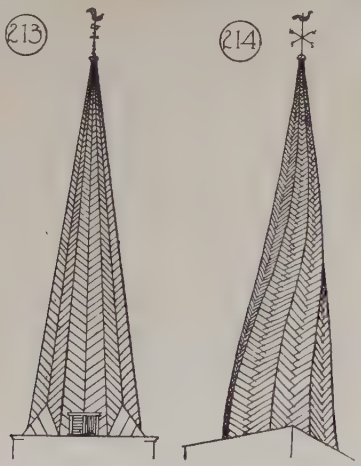


to form a miniature parapet gutter on dwelling-houses in France, the lead being brought over the top to protect the top edge of the woodwork. In some cases in England the sheets of lead were simply carried over the ends of the rafters at the eaves, and the water allowed to drip from them. The choir of Canterbury has an enriched lead parapet, and at Lincoln is another lead-covered wooden parapet which looks very much like stone.

England possesses many lead spires of various forms, but from a purely constructional point of view their

[1] Based on diagrams in Viollet-le-Duc, *op. cit.*

importance to us as regards leadwork lies chiefly in the method by which the lead was secured. The surface being nearly vertical, the metal sheets are apt, by their own weight, to tear at the nail-holes. They should therefore be laid with diagonal rolls, as shown in Figs. 211 and 212. Many examples have vertical rolls, but Figs. 213 and 214 show alternative diagonal treat-



ments from Godalming and Chesterfield respectively. The famous twisted spire at Chesterfield has been held up as an example of 'architectural refinement', but, so far from being intentional, this twist appears to be only an exaggerated instance of timbers warped by time. A recent article [1] on the restoration of this spire attributes its present dangerous condition to 'the ravages of worm, wet, rot, and beetle'; adding that the twist cannot be due to the sun, 'for the twist goes anti-

[1] Published in the *Architect* for 12 January 1923.

sunwise—west to east'. It is stated that 'some of the external leadwork on removal was found to have lost about two-thirds of its original weight from oxidation'. The architect for the restoration also called attention to 'the excessive condensation that appears to go on day by day in the steeple: the air, being heated up so much by day, condenses rapidly by night, and so causes oxidation of its ironwork. Under leaden flat roofs condensation is a recognized trouble, but is, of course, far worse in the case of the spire. To counteract this in some measure, it is the intention to improve the ventilation at the top'. Most of the great spires of the past have perished, among them that of Old St. Paul's, the loftiest of all, rising more than 260 ft. above the great tower below. At Amiens is a wonderful lead *flèche*, and in England a few leaded 'spirelets'.

During the Middle Ages the plumber, unlike most craftsmen, was often paid by the piece. Records of work by the hour vary very much, from 5*d*. to 11*d*., and from 4*d*. to 6*d*. for an assistant or 'server'. The wood for his work appears in medieval builders' accounts as 'tallwood' or 'byllettes'.

Towards the end of the sixteenth century the use of lead down-pipes and ornamental pipe-heads was introduced into England and soon became a characteristic of our architecture. For a century and more English plumbers occupied the pre-eminent position hitherto held by French craftsmen. The exact date of the first ornamental pipe-head has caused much controversy, but there is no need to discuss it here. From *c*. 1580 to *c*. 1620 the forms were essentially English, hardly influenced at all by the foreign artists imported during

the Renaissance. The Gothic gargoyle or spout was reduced in length to form a box, from which the water descended in a square pipe. These boxes were sometimes long in shape (Fig. 215), sometimes tall and narrow (Fig. 216), thus forming 'either glorified gutters or glorified funnels'.[1] The early heads were supported by nails passing through the ears and by iron staples passing under the 'box'. The latter was cast in sheet lead, the cornice being beaten into shape over a pattern, and the top edge sometimes cut into ornamental crenellations. Traceried disks, cast separately, were often applied to the heads or the ears, the nails passing through them in the latter case (Fig. 217). Pierced 'lacework' is freely used in the decoration of the Knole heads (Fig. 216). At St. John's College, Oxford, are some remarkable pipe-heads, decorated in heraldic colours and gilding, and recently restored.[2]

Figs. 216 and 218 illustrate ornamental gutters from Winchester and from a cottage at Bramhall, Cheshire, respectively. Fig. 219 shows a pipe from the same cottage, justifiably regarded by Sir Lawrence Weaver as 'the most beautiful pipe in England'. It is 4 ft. 4 in. long and $4\frac{1}{2}$ in. by $2\frac{1}{4}$ in. externally. 'The ornamental front is a casting soldered to an unornamented channel section to form the pipe.'[3] Pipes of this period are always rectangular and wider than their depth. One example at least has a curved front. Water from the rain-water gutters and pipes was often collected in an ornamental lead cistern, but few now remain.

The lead covering of roofs during the period 1580–

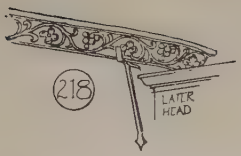
[1] Weaver, *Leadwork*, p. 38.
[2] Illustrated in Weaver, *op. cit.*, pp. 41–3.
[3] *Ibid.*, p. 37.

1650 presents no features of interest, and Sir Lawrence Weaver [1] has exploded the idea that Nonesuch Palace was covered with sheets of lead, as Pepys stated.[2] But lead was used for lanterns and angle turrets, though the bulbous lead spire that was so familiar a feature in Baroque buildings of Central Europe never became popular in this country.

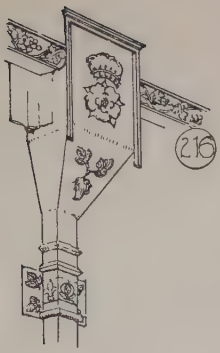
During the later Renaissance in England (*c.* 1650–1750) leadwork underwent the same change that we have already witnessed in the other crafts. The plumber ceased to design in his own way. He carried out the instructions of the architect, who in his turn sought 'inspiration' from measured drawings of Palladian buildings in Italy. So we find pipe-heads, like plaster ceilings, taking unto themselves classical mouldings and classical forms from the copybooks. The craft, however, died slowly, and Fig. 220 shows a typical example (from Petworth) of its later state. Heads of this period are made from lead varying from 7 to 12 lb. per sq. ft., and averaging about 12 lb. Ornamental gutters were occasionally used, and the forms varied little, though circular pipes are now found in the angles of a building. Pipes were sometimes worked with a spigot-and-socket joint, the bore being thus reduced at every joint with a corresponding loss of efficiency.

The use of large ornamental lead rain-water cisterns now became common. Their form was almost always oblong, but often they tapered slightly upwards, this making cleaning the more difficult. (For drinking-water, of course, their use was never wise.) Externally

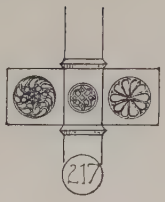
[1] Illustrated in Weaver, *op. cit.*, p. 143.
[2] Pepys, *Diary*, 21 September 1665.



2.18

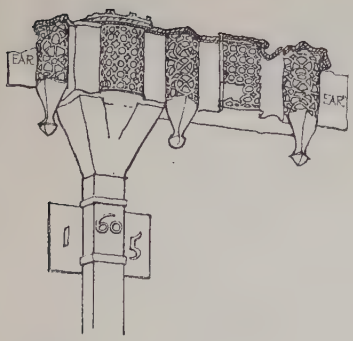


2.16

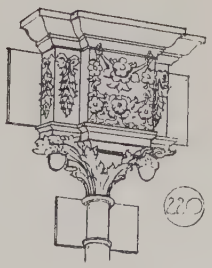


2.17

2.19



2.15



2.20

they were decorated with ribs forming panelling, with applied cast ornaments, or with elaborate bas-reliefs. They were strongly constructed of heavy cast sheet-lead, with lead stays and bars.

Wren used lead very largely on the dome of St. Paul's and on the picturesque steeples of his City churches, but did not favour the diagonal rolls of his 'Gothick' predecessors. Most of these steeples have turned black with City smoke and acids, so that they have none of the silvery *patina* of country churches, but supply a contrast with the white Portland stone towers beneath them. It is remarkable that the lead on many of these spires, as on other old buildings, is not nailed to close boarding, such as we should use, but to battens, spaced several inches apart, and, in one case at least, fixed diagonally. Lead-headed nails are used in some cases, clips in others.

But the chief event in plumbing of this period was the invention of milled lead in the last quarter of the seventeenth century. Wren seems to have employed it with disastrous results at Greenwich Hospital in 1700, and it was a long time before improved methods of manufacture made it generally acceptable. After 1750 the interest of leadwork as a craft declined; it became mechanical, and only in staircase balustrades and other minor ornamental details do we find lead used with any sense of its decorative possibilities.

In recent years the supply of the metal for England has depended more and more on imports from abroad. At the beginning of the nineteenth century the bulk of the lead supply for the whole world came from England and from Spain. Even in 1850 England still headed the

list of producing countries, but in 1905 the tonnage had dropped to much less than half the figure for 1850, and since then the decline has continued. But the plumber is still an active member of our commonwealth, and this chapter may convince him that he can regard himself as the heir of a great artistic tradition.

XI

GLAZING

The story of the glazier's craft, with which this series of studies is concluded, affords an excellent illustration of the way in which all branches of building have developed in accordance with climatic and social conditions. It furnishes us too with occasional instances of bad craftsmanship among the builders of old, as well as with innumerable examples of that extraordinary devotion to art which is one of the most satisfying features of medieval life.

Glazing is an accessory rather than a prime necessity in a warm climate; hence we do not find the beginnings of its history in Egypt or Assyria, as we have done in the case of most of the crafts dealt with in previous chapters. The so-called 'windows' in the clerestory of the Hypostyle Hall at Karnak, like the charming example from Denderah in the British Museum, were really great stone grilles to admit light in small patches, and were unglazed. Windows are not usually provided in the peasants' cottages that one sees in the Nile valley, because a chink of light, under the door or between its boards, is enough to furnish all that is necessary. Shade is what one seeks in Egypt. On summer nights the cottage door may be left open for coolness. In the winter the cold is often so intense that the door is kept shut, and, if there are any other small openings for light, they are closed with shutters. But in better-

class houses in Egypt windows are always provided nowadays, if only to protect the rooms from the terrible sand-storms that periodically sweep the country. Yet the art of glass-making, though not applied to windows, may have been practised there as early as the twelfth dynasty, and was certainly practised in later periods. It was once thought that this industry might have come to Egypt from China, where it is said to have been established as early as *c.* 2300 B.C., but that is not yet an accepted fact. Though all the ingredients for glass-making were available in Egypt, no remains of the industry in a primitive condition have been found. There is a wall-painting, possibly of the eleventh dynasty, at Beni Hasan, which, according to some writers, accurately depicts the process of glass-blowing, but Professor Flinders Petrie considers[1] that it represents a metallurgical process. Possibly it may be a traveller's recollection of glass-blowing seen in a foreign country. Pliny cites a tradition ascribing the discovery of glass to Syria, and it is known that glass-makers were imported into Egypt from Syria in the eighteenth dynasty, the earliest date at which glass is known with certainty to have been made in the former country. On the whole, the claims of Syria and Egypt seem to be fairly evenly balanced. Professor Capart in a recent book states that ' transparent glass and blown glass did not make their appearance until the Roman period '.[2] A large glass-manufactory of the eighteenth dynasty was, however, discovered at Tel el-Amarna. Most of the glazing done at that time was confined to glazed

[1] Petrie, quoted in *Encyclopaedia Britannica*, s.v. ' Glass '.
[2] Capart, *Egyptian Art*, p. 95.

pottery of various kinds. In no case do we find any reference to glass windows, and, as it is with these that this chapter is concerned, we may turn away from Egypt.

It does not appear that the Greeks ever used glass windows; certainly not in their temples, and their houses were generally of a lower standard of architectural finish. The window-openings in the Erechtheum may seem to provide an exception, but they are of Roman date. The method of lighting the temples, whether by clerestory or otherwise, has never yet been determined, but in Chapter VIII the transparent marble-tiling and the openings in the roof were mentioned.

In the colder climate of Rome, glazed windows were largely used in later days, when ideas of comfort and even of luxury had considerably advanced. The Pantheon had its famous top light (unglazed), and earlier buildings had unglazed openings for light, but at the beginning of the first century A. D. glass made its appearance in windows. By this time glaziers were sufficiently numerous to have a street allotted to them. Vitruvius[1] gives a simple (and rather obvious) rule for testing the amount of light necessary in a room whose windows are obstructed by other buildings, but says nothing of glass. Caligula glazed the windows of his palace in A. D. 37–41. The numerous remains of glass existing from the later centuries of the Empire, in Pompeii especially, but also in all parts of Western Europe, including Gaul and Britain, enable us to form some conclusions as to its nature and use. It appears to have been cast in small sheets, to have been fairly clear and

[1] Vitruvius, VI. vi. 7.

of a greenish tint, and to have been from $\frac{1}{8}$ in. to $\frac{2}{5}$ in. thick (the latter thickness having been found in a window 2 ft. 8 in. by 3 ft. 8 in. glazed in one sheet without bars). As a rule, window-panes were about 12 in. high, and were often square. The glass was cemented, or fixed with nuts and screws, into frames made of wood, bronze, copper, or even lead.[1] In large buildings, such as the basilicas, it may have been fixed in pierced marble panels. Most of the window glass was cast, but at Silchester fragments of sheet-glass were discovered. Other materials used for window-panes were mica, alabaster, and shells. Obscured or ground glass has been discovered, and coloured glass is said to have been used by the very early Christians. There is a bow-window looking out on to the garden in one of the villas at Pompeii. The large number of specimens of Roman glass preserved at the British Museum and elsewhere in England bear witness to the durability of its composition. At Wilderspool, near Warrington, a presumed Roman glass furnace has been found, but it does not appear to have been of much importance. Professor Lethaby writes that there were glass-works in London and Silchester,[2] but is of opinion that the 'metal' was imported. Much of the glass used in Rome was imported from Alexandria or Memphis.

During the Dark Ages the progress of glazing in Western Europe was naturally slow. In Roman times there were glass-works in Normandy and Poitou. Glass windows were still being made in France in the fifth century, and it was to France that Benedict Biscop

[1] Day, *Windows*, p. 3; and Middleton, *Rome*, vol. i, pp. 31–2.
[2] Lethaby, *Londinium*.

sent for glass-workers in 675, when he wished to glaze the windows of his church and monastery at Wearmouth. 'They came', says Bede, 'and not only did the work required of them, but taught the English how to do it for themselves.' In the same century the windows of the old minster at York, which formerly had been lighted through pierced linen or perforated boards, were filled with glass. Yet in 758 we find the Abbot of Jarrow appealing to the Bishop of Mainz to send him a craftsman in glass. According to Muratori it was not until the seventh or eighth century that church windows in Italy were glazed. At Peterborough, even as late as 1190, forty windows in the nave of the cathedral had to wait twenty years for their glazing, being filled meanwhile with reeds and straw to keep out the rain. Glass was only used in the larger or richer churches, while for domestic buildings it was apparently never employed. Even in the halls of the great feudal castles, the wind whistled through unglazed window openings on winter days, and even if wooden shutters were used at night, as described below, they would hardly be practicable in the daytime.

It may have been the scarcity and expense of glass that accounted for the very small size of the windows in Anglo-Saxon and early Norman churches. Moreover, a wide window was more difficult to glaze than a narrow one under the prevailing conditions of manufacture. Either explanation is more plausible than that of an Italian writer who suggests that a 'dim religious light' was intentionally aimed at, this being a typical modern idea of 'design' that would hardly have entered the brain of a practical man like the medieval builder.

A third possible reason for small windows, seeing that such windows were usually placed high up in the wall, was that the church was, in these early days, still a place of refuge on occasion. The normal and almost universal Romanesque window in all countries, as in Roman and Byzantine architecture, had a semicircular head. The glass was placed close to the outer face of the wall, with a wide internal splay to admit light. As the width of the opening was increased, after the Norman Conquest, it became necessary to support the glass against wind-pressure by horizontal saddle-bars let into the masonry at each end and by vertical iron stancheons. Where glass was not used, as in many small churches and probably all domestic buildings, the ordinary method of closing an opening was by means of wooden shutters, sometimes pierced with a round hole, hung on iron hooks, and opening either inwards or outwards.[1] The Anglo-Saxon word for 'window' means literally 'eye-hole', and evidently little more than an eye-hole was expected. But in some Anglo-Saxon churches one finds thin slabs of stone pierced with ornamental patterns, closely resembling those used in the Byzantine Empire in Syria, and in Coptic Egypt at the same date, and afterwards so characteristic of Saracenic architecture. We know that Greek glaziers were brought to France in the seventh century, and at this point we must consider the influence of the East on the craft, for, as Mr. Lewis F. Day has said, 'Coloured glass comes to us from the East, that much it is safe to conclude'.[2]

[1] I have been informed that at Birstall Church, near Leicester, is a blocked-up Norman window containing the remains of a wooden 'transenna' with intersecting circles.

[2] Day, *op. cit.*, p. 3.

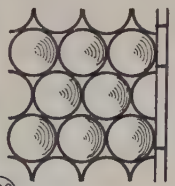
The earliest use of stained and painted glass in Western Europe may possibly date back to the time of Charlemagne, i. e. about A. D. 800. But long before that date it was probably employed at Constantinople, and thence it passed westwards through the Byzantine cities of Ravenna and Venice to Limoges in France, where a colony of Venetian glass-workers settled in 979. Very little is known about this Byzantine glass, and Sir Thomas Jackson considers that it was seldom used in churches where the walls and vaults were decorated with mosaics, as there would then be too generous a provision of colour, and full justice could not be done to the mosaics, which, after all, were the chief element in Byzantine architectural decoration.[1] But the nature of this early glass closely resembles that of contemporary mosaic and enamel, and may best be understood by a reference to the much later but probably identical work of the sixteenth and seventeenth centuries in Cairo, Jerusalem, Damascus, and other Muhammadan cities.

Fig. 221 illustrates one of these ' pierced lattices ', and is typical of most others. It consists of small pieces of coloured glass let into a panel of plaster. The various perforations are splayed or bevelled on the inside, the angle being adjusted according to the height of the window, so that the light is not obstructed. The plate of plaster is sometimes not more than $\frac{1}{2}$ in. thick, is strengthened by iron bars, or by ribs of cane if of large size, and is frequently fixed in a wooden frame. The glass is often of poor quality, but appears to great

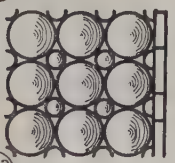
[1] T. G. Jackson, *Byzantine and Romanesque Architecture*, vol. i, p. 27.

advantage against strong light because of its opaque setting, the area of the solids usually exceeding that of the voids, and the size of the small perforations often not exceeding an inch. The effect has often been compared to 'jewels of light', and, when one reads of 'jewels' in the *Arabian Nights* and other Eastern fables, coloured glass is generally implied, not precious stones.[1]

221



222



223

It was these 'mosaic' or 'jewel' windows that inspired the first stained glass of the Romanesque craftsmen. Very few examples earlier than the thirteenth century remain, and those mostly in France, but the western windows were set in wide 'cames' of lead. The glass was of deep strong colours, hardly any white being used, and gained immensely in effect through the amount of opaque lead that was employed. Viollet-le-Duc mentions an example of 'faked' lead

[1] On Saracenic window-glass, see my *Muhammadan Architecture, &c.*, pp. 227–9.

glazing of early date (in appearance not unlike the central panel of the example from Aix-la-Chapelle illustrated in Fig. 224) where some of the lead bars were not cames but merely applied strips.[1] This, however, was unusual, and early glazing was generally notable for the strength and sincerity of its leading. In Byzantine architecture 'roundel' glazing is also common (of the type illustrated in Figs. 222 and 223, though these are taken from much later examples). The windows of St. Sophia were filled with plates of glass let into pierced marble frames. Some of these, which are cast and not blown, still remain, and may date from the building of the church. Writing of Monreale and other Sicilian churches where the influence of the Saracens is very marked, Sir Thomas Jackson quotes Professor Salinas to the effect that

'They were originally lighted dimly by windows filled either with sheets of lead pierced with small openings, or with traceries of plaster, at first unglazed, and afterwards glazed with coloured glass. This leadwork was employed in the cathedrals of Monreale and Palermo, so that the scarcity of light might "strike a sacred horror".'[2]

In the thirteenth century in England the windows of castles were first glazed, but for a long time this was most unusual, and a nobleman travelling from one house to another often carried his glazed casements with their wooden frames among his personal luggage. Oiled canvas was used in the windows of the Chapter-house at Westminster in 1253, and wooden shutters were far

[1] Quoted in Day, *op. cit.*, p. 24.
[2] T. G. Jackson, *Gothic Architecture*, vol. ii, p. 286.

more common than glass. In the hall of Stokesay Castle (*c.* 1240–90) is a tall two-light window of which the upper part (above the transome) was glazed and the lower part furnished with wooden shutters. Below this window are two stone window-seats. We have no evidence that the glass-making industry was practised in this country between the departure of the Romans and the thirteenth century, when a deed of 1230 granted certain land at Chiddingfold in Surrey to one Lawrence

224

'vitrarius'. Chiddingfold, now an obscure village, seems to have been the centre of glass manufacture in England and an important place. It was well wooded, and thus abundant fuel was close at hand. Some of the window-glass (apparently white) for St. Stephen's Chapel at Westminster was made at Chiddingfold in 1352 by John Alemayn (Aleman), a name which hints that foreign influence in this craft was still strong. But there is evidence that no window-glass was being made at Chiddingfold by 1567, indicating that the glass-makers had now migrated to Sussex, Hampshire, and Gloucestershire. The two kinds of glass used in England during the Middle Ages were 'brodeglas' and

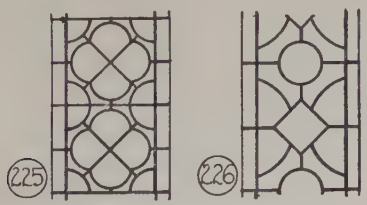
'Normandy' glass, corresponding to the sheet-glass and crown-glass of modern terminology.[1]

In churches the width of windows was now increased, partly because the use of stained glass reduced the amount of light. The glass continued to be placed near the outside of the wall, but a dripstone was introduced to protect it. The use of vertical iron bars, which at first had divided the design into rectangles, was now varied by the addition of 'medallions' (Figs. 225 and 226), which soon became a characteristic feature of the period. The glass itself was thick, uneven, and of a greenish tint due to impurities in its composition. When coloured, it was 'pot-metal', that is to say, the colour was burnt into it, and painting on the surface was hardly employed in these early days, except to touch up features, &c. The use of the diamond was unknown, and glass was laboriously cut by passing the point of a red-hot iron over the surface. Hence simple shapes were aimed at in design. The glaziers seem to have been few in number, and to have worked in small groups. They drew out their designs on a whitened bench, on which the glass was afterwards put together, and thus the design would be destroyed unless copies were made on sheets of parchment and preserved, as was probably the case.[2] The thirteenth century also saw the introduction of *grisaille* glass (in light tints), and probably the foundation of the famous works at Murano near Venice. It is uncertain whether the first glass-

[1] On early glass-making in England, see article 'Glass' by H. J. Powell in *Encyclopaedia Britannica*.

[2] On technique of medieval glaziers, see Day, *op. cit.*; and H. Arnold, *Stained Glass*.

workers at Venice were Italian refugees from the mainland in the fifth century, or craftsmen from Constantinople, but it is recorded that the industry was established on the lagoons in 1090. Writing of windows in Italian Gothic palaces, Sir Thomas Jackson states that the glass is set in wooden frames fixed behind the marble or stone colonnettes that appear externally.[1] He also tells us that painted glass was never intended to be used as a general rule in Italian churches. The windows were of small size compared with those in



England, and where coloured glass has been fixed, as in the Lower Church at Assisi and in Florence, 'it wraps the interior in an oppressive gloom'.[2]

Nothing is more remarkable in English architecture of the fourteenth century than the great importance given to stained glass. At Gloucester especially every effort was made to reduce masonry to a minimum in order to provide an uninterrupted expanse of 'storied windows'. With the same object in view, flowing tracery gave place to a rectilinear treatment, for, just as—according to Ruskin—stained glass 'spoils all traceries',[3] because it dims the silhouette, so tracery,

[1] Jackson, *Gothic Architecture*, vol. ii, p. 206.
[2] *Ibid.*, p. 219.
[3] Ruskin, *Seven Lamps of Architecture*, III. xix, p. 170.

in a way, confuses the design of glass though it supports it against the pressure of the wind. Windows were now set farther back in the wall to protect the painted glass. Massive rebated bars of iron, known as framing bars, were fixed horizontally in the stonework every 3 or 4 ft. in the height of the larger windows, and light saddle-bars were fixed between these and *inside* the glass. To these the glazing was attached by means of strips of lead (called 'bands') soldered to the leading of the glass and twisted round the bars. (Nowadays copper wire is used for the purpose.) The craze for stained glass, as Mr. Bond says, 'spread like wildfire through the length and breadth of England',[1] and the process of manufacture was greatly improved. Instead of being thick and opaque, as in the previous century, it became thin and translucent, the mass of deep colour being reduced to a minimum. The white (strictly speaking, greenish) glass of the background was divided into diamond-shaped 'quarries', this form probably having been suggested by the light 'lattices' of interlacing twigs that preceded glazing in the windows of earlier cottages. The introduction of 'stippling' and of 'yellow stain'—technicalities that cannot be described here—also greatly influenced stained-glass design of the period. Window-glass was one of the commodities obtained largely from the Flemings in exchange for English wool, and was imported also from Venice, Normandy, and the Vosges. In an old account-book of about 1500, it is noted that Flemish glass then cost 4*d.* a foot; Dutch 4½*d.* and 6*d.* 'Venyse' 6*d.*; ('for the kitchen'); 'Normandy' 6*d.*; and English quarries 1*d.* each (though

[1] Bond, *Gothic Architecture in England*, p. 499.

ordinary quarries cost ½*d.* each). Glass seems to have been delivered, as nowadays, in cradles or crates. The glazier was generally paid by the piece, occasionally by the day. An entry of Henry VIII's time records a payment to a glazier of 16*d.* for four days work, in addition to 8*d.* for four days 'bord'. Other documents give wages varying from 6*d.* to 8*d.* a day, and 3*s.* to 3*s.* 4*d.* a week. In domestic buildings of this period shutters continued to be used, as well as both wooden and iron casements.

The fifteenth century witnessed a further development in stained-glass manufacture, chiefly due to the prosperity in the wool-trade, which accounted for so many fine churches in the West and in East Anglia. For a time English craftsmen surpassed the Continental glaziers in the beauty and skill of their work. The glass itself was thinner, flatter, and of a more even colour. The invention of *verre doublé* extended the range of the artist's palette. But the main change took place in the arrangement of the leading, which now became subservient to the 'picture', instead of defining and limiting the whole design. Mr. Lewis F. Day points out [1] that, up to this period, the design might be inferred from the leading *externally*, but that thereafter this commendable treatment was discontinued. The pieces of glass became much larger, and the idea of mosaic was lost. Painting with the brush became more and more general.

In domestic work glazing had not yet become universal, and sheets of horn were sometimes used to keep out the wind. But windows were often fitted with seats, they served as 'leaning-places' for conversation, and in the

[1] L. F. Day, *Windows*, pp. 60–1.

halls of the larger houses the great bay-window by the daïs formed a notable feature. On the Continent the fourteenth century saw the introduction of 'roundel' glazing (illustrated in Figs. 222 and 223) as a background.

The two principal centres of glass-painting in the Middle Ages were York and London, for the North and the South of England respectively, but nearly all the coloured glass and most of the white was imported from abroad. The chief glass-painters at York were men of good social standing, two becoming Lord Mayors of the city and one representing it in Parliament. At an early date the glass-painters in York formed a craft-guild. It seems that there was need for such an organization, for, according to Mr. J. A. Knowles,[1]

'There was as much scamping as there is to-day, and probably more; and that glass-painters were no exception is shown by the minute stipulations in contracts that the paint should be fired on in the kiln and not merely mixed with oil.'

During the earlier part of the sixteenth century the bay-window continued to develop, but glass windows were by no means general, and were still regarded in the eyes of the law as 'movable furniture'. A certain amount of glass continued to be imported from the Continent, and there was constant intercourse with the Flemish school of glass-painters. In this craft may be noticed signs of decadence and a departure from English tradition towards mere picture-painting. It is probable that the use of the diamond was not introduced

[1] Lecture on 'The York School of Glass Painting', reported in the *Builder* for 24 August 1923.

until the following century. Among means for cutting employed, in addition to that already described, may be mentioned a pair of shears under water, and a piece of red-hot charcoal.

'The charm of medieval glass', writes Mr. Day, 'lies to a great extent in the material, and especially in the inequality of it. Chemically impure and mechanically imperfect, it was rarely crude in tint or even in texture. It shaded off from light to dark according to its thickness; it was speckled with air-bubbles; it was streaked and clouded; and all these imperfections of manufacture went to perfection of colour. And age has improved it: the want of homogeneousness in the material has led to the disintegration of its surface; soft particles in it have been dissolved away by the action of the weather, and the surface, pitted like an oyster-shell, refracts the light in a way which adds greatly to the effect; at the same time there is roothold for the lichen which (like the curtains of black cobwebs) veils and gives mystery to the colour. An appreciable part of the beauty of old glass is the result of age and accident. In that respect no new glass can compare with it. There is, however, no such thing as the "lost secret" of glass-making. It is no secret that age mellows.'[1]

Many admirable text-books have been written on the technique of stained glass, and it is to them that the reader must refer for fuller description and illustration of an unrivalled medieval art than can be attempted in a small work like the present general study of old-time crafts. But it is a remarkable fact that, although paintings on canvas can be attributed, for the most part, to their known authors, the names of so many of the craftsmen who produced the lovely windows of the

[1] Day, *Windows*, p. 101.

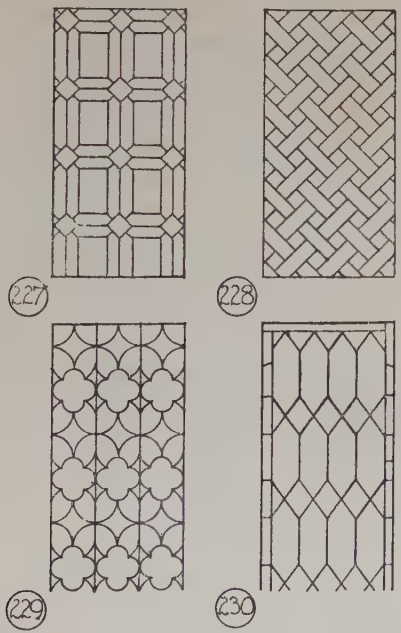
Middle Ages are long forgotten.[1] Like the sculptors of contemporary statuary, their personalities are lost in the glory of their age.

The Dissolution of the Monasteries, and the Puritan movements that followed, resulted in the destruction of much of the existing stained glass in churches, and, except for a brief revival under Laud, the art was now chiefly restricted to windows in colleges and large houses. But the invention of 'enamel paint' changed its character. From about 1550 onwards, this medium came into general use, completely superseding the earlier and richly coloured 'pot-metal'. Colour as used in the Elizabethan and Jacobean periods was restricted to brown and yellow medallions painted on a white background divided into geometrical patterns by leading, and occasional escutcheons with full heraldic colouring. In these medallions leadwork ceased to play any organic part, indeed it was avoided as far as possible. A layer of white enamel paint on the back of the window produced a somewhat opaque effect.

But the development of window-design was remarkable. The bay-window was now carried up several stories, and became the most striking feature of the Elizabethan façade, while smaller mullioned windows were freely used. Glassworks were opened in several places, especially in the well-wooded districts of Kent and Sussex where fuel was plentiful, and a thriving English industry grew up. But it was largely under the direction of experienced glass-makers from Lorraine and Normandy, who had been driven from France as the

[1] There are, however, records of many individual craftsmen in Oxford, Winchester, London, and especially in York.

forests were thinned, and who even in England were continually migrating for the same reason. In 1615 or 1616 coal was first used in manufacturing glass, and the use of wood fuel was prohibited. The plain glass of this



period varied greatly in tint. It was set in lead cames about $\frac{3}{8}$ to $\frac{1}{2}$ in. wide, arranged in diagonal or lattice patterns at first, but in rectangular panes from about the middle of the seventeenth century. But ornamental patterns were also used (Figs. 227 to 230), especially in the larger houses. For cottages they were not so much favoured, as they presented difficulties for the

village craftsman. In 1615 was published a book of designs by one Walter Gedde entitled

'A Booke of Sundry Draughtes. Principally serving for Glaziers; and not Impertinent for Plasterers and Gardiners: besides sundry other Professions. . . .'

This book, opening with a preliminary chapter on what we should call 'setting-out', contains 66 plates of 'square draughtes' (i. e. rectilinear patterns), and 37 of 'Sundrie sortes, of Circular, or Compas Draughtes for Glasing'; suggesting Saracenic patterns in their intricacy and ingenuity. He concludes with a description of the process of annealing, and notes entitled 'The Receiptes, for the true making of Collours for Glasse' of which the following is a specimen.

To make a faire Blacke.

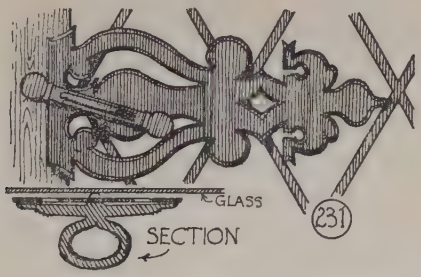
'TAKE the Scales of Iron & Copper, of each a like waight, & put it in a cleane vessell that will indure the fire, till they be red hotte, then take half as much Ieate, and stamp them into smal pouder, then mix them with Gumwater, & grind them fine upon a painters stone and so drawe with it upon your glasse.'

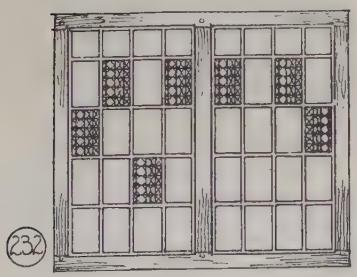
To make green, he uses 'Vertegrease' and Turpentine; for 'a faire red' he recommends 'Sanguis draconis . . . with a little Aquavitie'; for carnation 'Tyn-glas, . . . Ieat . . . gum . . . and red Ocker'; and for yellow 'Silver . . . Antimonium . . . Ocker', &c. This book is dedicated 'to the willing practisers of glazing, and anneiling in Glasse', and the preface concludes thus:

'So by observing the order and rules set downe, the maister or workeman shall not only see a plaine way, to imitate and follow these draughts, in glazeing and painting on glasse: but the simplest, and unskild

prentice, shall reape full and perfect understanding thereby: praying the Almighty, to blesse your labours in following the same.'

All over England are delightful examples of the glazier's art in the sixteenth and seventeenth centuries. They





include many examples of ornamental casement-fasteners (Fig. 231) and stays, and a certain number of lead ventilating-quarries (Figs. 233 to 238) of which Fig. 232 shows the application.

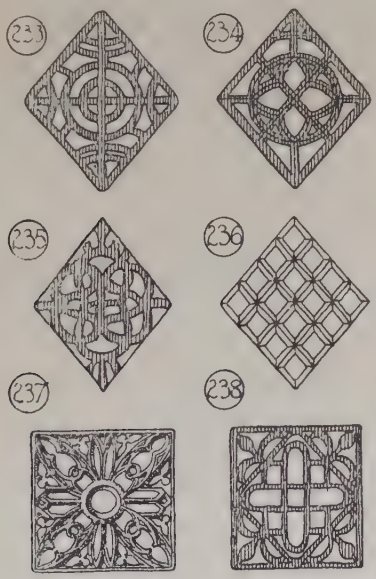
Lead glazing persisted up to the end of the seventeenth century, although the sash-window was introduced much earlier and is found at Inigo Jones's houses—Raynham (1630–6) and Coleshill (1650)—as well as in John Webb's

houses in Great Queen Street, London (1640). At first only the lower part of the sash was movable, being kept up by a series of notches and a catch to hook into them. Late in the century, and probably introduced from Holland, came the modern method with weights, pulleys, and cords. The wooden bars of these windows were very stout, and not mitred but constructed with a mason's joint. For some time sash-frames were set back at most 2 in. from the wall-face and were often flush, but an Act of 1709 (only recently repealed), insisted that in London they must be set back at least $4\frac{1}{2}$ in. as a precaution against fire spreading from room to room.

The English word 'sash' is derived from the French *chassis* (frame), and Moxon, at the end of the seventeenth century, spells it as 'shas'. Yet curiously enough the French seem to have borrowed the idea of these windows from us. A case is recorded of a Frenchman who in 1699 showed some English travellers the sash-windows in his new house at Montmartre, saying that they were made from a model brought specially from England, as there was nothing of the sort in France.[1] The tax or duty on windows was first applied under William III in 1695. It was renewed many times, but was finally repealed in 1851, when 'house-duty' was instituted to take its place. The adoption of the sash-window was very gradual in this country. Thus, in the Palace at Winchester, begun in 1685, the windows had wooden frames, iron casements, and leaded lights. Leaded casements persisted fifty years later for cottages

[1] Innocent, *Historical Development of English Building Construction*, p. 262.

in remote districts, and for the dormers of larger houses. Abreast of the sash was also used the ' Yorkshire light ' or sliding window, of which the origin is so obscure that one authority [1] defines it as ' A term used in *Lancashire* for a sliding sash '.



Of the examples of painted glass of this period (including the windows at New College, Oxford, where the ' Virtues ' designed by Sir Joshua Reynolds peer at the spectator through the heavy metal bars that he ignored in his design), the less said the better. But it is hardly fair to regard them as characteristic of contemporary craftsmanship, which was continued without

[1] *Dictionary of the Architectural Publication Society.*

intermission on more or less traditional lines up to its revival nearly a century ago. There has been a genuine revival of stained-glass work in comparatively modern times, which has produced windows of the highest merit. It began early in the nineteenth century, it rose suddenly to a high plane in the hands of Burne-Jones and Morris, and a group of later artists have restored it to something like its former excellence. Here too one may learn a lesson, for the earliest work of this revival, when direct copyism of medieval examples was encouraged by architects, was far inferior to the work of Burne-Jones and his successors, who adapted the spirit rather than the letter of the past to modern needs.

The eighteenth century saw little change in glazing, the only features of interest being the progressive attenuation of the sash-bar, and the revival under the brothers Adam of decorative glazing in fanlights. The rolling of large plates was introduced by the French in 1688, and when new glassworks were built at Ravenhead near St. Helens in 1773, French workmen were brought over. The shallow segmental bow-windows of late Georgian houses are very attractive. But glazing, like the other crafts, shows a story of development and decline, losing its vitality as copybook revivalism took the place of traditional work by practical and simple-minded men. The present century has provided the architect with problems from which he often shrinks with horror because the past furnishes him with no obvious precedents. Which of his copybooks tells him how to deal with a huge expanse of plate-glass, or with the vast glazed façade of the modern factory? Here he has to do what the builder of the past often had to do—think for

himself! In regard to glazing there is much hard thinking still to be done by architects, and so it should be in all the building crafts. The knowledge is there; the skill is there. If the modern craftsman is content to be inspired by the past rather than bound by it; if the modern patron of art, whether individual or corporate, will trust him, instead of demanding 'reproductions from the antique'; if the architect will forget his copybooks and study the past in a sensible way; then, in all its branches, building may become, as it was long ago, the visible expression of the needs of a cultured people.

INDEX

Aachen, early bronze work at, 176.
  glazing at, 268.
Adam, the brothers, 159, 195, 229, 236–7.
Aegina, masonry at, 77, 79.
  plastering at, 226.
  temples at, 79.
  tiling at, 204.
Aix-la-Chapelle (*see* 'Aachen').
Alabaster, use of, 72.
Albi Cathedral, brickwork at, 54.
Alder, 119.
Aldrich, Dean, 36.
Alemayn, John, glazier, 269.
Alexandria, 3, 38, 263.
Alfa grass, use of, 40.
Alhambra, stucco work at, 230.
Amalfi Cathedral, bronze doors at, 176.
'Amateur' architects of XVIIIth century, 36.
Ambler, L., *quoted*, 96.
America, early brickwork in, 62.
  use of shingles in, 214.
Amiens Cathedral, lead *flêche* at, 254.
Ancones in Greek masonry, 80.
Anderson and Spiers, *quoted*, 44 *n.*, 77 *n.*, 80 *n.*, 84 *n.*, 108 *n.*, 119 *n.*, 120, 173, 229 *n.*
Angoulême, roofing at, 209.
Antefixae, 205, 206.
'Arabian Nights', *quoted*, 267.
Architect, the, 7–36, 71.
  Byzantine, 18.
  Egyptian, 13.
  Greek, 14.
  Medieval, 22–3, 27–31, 100.
  Roman, 16.
  Renaissance, 31–6, 71, 100–1.
  Victorian, 36, 53.
Ariconium, Roman ironworks at, 174–5.
Arles, Amphitheatre at, 82.
Armenian masons and masonry, 19, 84, 85.
Arnold, H., *quoted*, 270 *n.*
Arnolfo del Cambio, 30.
'Arts and Crafts' movement in England, 36.
Ashbourne Church, 91.
Aspdin, Joseph, 114.
Assisi, stained glass at, 271.
Assyria, brickwork in, 40, 41–3.
  bronzework in, 172.
  carpentry in, 118.
  craftsmanship in, 13.
  joinery in, 146–7.
  masonry in, 76.
  plastering in, 224–5.
  roofing materials in, 204.
  use of iron in, 172.
Aswan granite, 72–4.
Athens, the Arsenal at Piraeus, 118, 204.
  Areopagus at, 208.
  Erechtheum, 148, 262.
  masonry in, 77–80.
  Monument of Lysicrates, 206.
  Parthenon, 14, 78, 79, 204, 206.
  Propylaea, 14.
  Walls of, 44.
Attlee, T. S., *quoted*, 16–18.
Augsburg, door from, 180.
Augustus, emperor, 44.
Auvergne, polychrome masonry in, 88, 98.
  use of lead roofing in, 206.

Baalbek, *trilithon* at, 84.
Babylon, use of iron in, 172.
  use of lead in, 241.
Bacon, *quoted*, 189.
Bankart, G., *quoted*, 225 *n.*, 226 *n.*, 229 *n.*, 232, 236 *n.*
Basalt, use of, 72, 88.
Bassae, temples at, 14, 79, 206.
Bath, Roman plumbing at, 241–2.

Beauvais Cathedral, 90.
Bede, *quoted*, 246, 264.
Beech, 131, 152.
Belgium, brickwork in, 52.
Bell, Edward, *quoted*, 41 *n.*, 204 *n.*
Benedict Biscop, 263–4.
Benedict, St., 21.
Beni Hasan, fresco at, 261.
Bennett, S. B., *quoted*, 245.
Bethersden marble, 88.
Birstall Church, *transenna* at, 265 *n.*
Bishop's Waltham, 91.
Blois, ornamental slating at, 216–19.
Blomfield, Sir R., *quoted*, 57 *n.*, 159.
Bologna, S. Petronio, 54.
Bond in brickwork, 'English', 39, 51, 56, 70.
'Flemish', 56, 70, 109.
Bond, F., *quoted*, 94, 95 *n.*, 210, 211 *n.*, 246 *n.*, 247, 272.
Bramante, 8.
Bramhall, leadwork at, 255.
Brandon, *quoted*, 125–6, 127 *n.*
Bricklayers' tools, 68.
Brickwork, CHAPTER II (37–71).
in America, 62.
Assyrian, 41–3.
Byzantine, 47–50, 111–12.
cost of early, 56.
in Crete, 43.
'Delta', 51–2.
early bylaws affecting, 63–6.
in East Anglia, 51, 55–6, 58–9.
Egyptian, 37–41.
Flemish, 55, 57.
Greek, 43–4.
Gothic, 52–8.
in Kent, 55, 58–62, 66–7.
in the Midlands, 62.
Renaissance, 62–71.
Roman, 44–7, 106–11.
Romanesque, 52.
Saracenic, 50–2.
in Surrey and Sussex, 58–62.
Victorian, 53, 71.
Briggs, M. S., *quoted*, 18–20, 51 *n.*, 52 *n.*, 86, 96 *n.*, 123 *n.*, 152 *n.*, 164 *n.*, 179 *n.*, 182 *n.*, 230 *n.*, 267 *n.*
British Museum, the, 145–7, 148, 164, 172, 174, 224.
Bronze work in Assyria, 172.
in Crete, 172.
Egyptian, 116, 171.
Greek, 172.
Roman, 173–4.
Romanesque, 176, 180.
Saracenic, 182.
Brunelleschi, 31, 134, 169.
Burford, 97.
Burlington, Lord, 36.
Burne-Jones, Sir E., windows by, 282.
Byzantine brickwork, 47–50, 111–12.
carpentry, 121–2.
concrete, 84, 111–12.
glazing, 265–6, 268.
ironwork, 176.
masonry, 84–5, 98, 111–12.
roof-tiling, 208.

Caen stone, 27, 90.
Cairo, medieval architects in, 18.
medieval craftsmen in, 18–20, 85.
gateways of, 85.
mosque of Ibn Tulun, 18, 50–1, 122, 230.
mosque of Sultan Hasan, 20.
Caligula, emperor, 262.
Callicrates, 14.
Cambridge, King's College Chapel, 247.
old Welsh slates at, 216.
Queen's College, brickwork at, 57.
Trinity College Library, carpentry in, 136–7.
Canterbury Cathedral, 22, 90, 180, 246, 250, 252.
Capart, Prof., *quoted*, 13, 41, 261.
Cardines, 148.
Carpenters' Company, the, 26.
Carpenters' tools, 116, 137–8, 171.
Carpentry, CHAPTER V (116–42).
Assyrian, 118.

Carpentry, contd.:
Byzantine, 121–2.
Egyptian 116–18.
Etruscan, 118, 120.
Gothic, 124–33.
Greek, 118–19.
Lycian, 118.
Renaissance, 133–42.
Roman, 119–21.
Romanesque, 123–4.
Saracenic, 122–3.
in Wren's time, 136–40.
Carron Foundry, the, 195.
Carshalton Park, ironwork from, 192–4.
Castor, door at, 152.
Caudebec, architect's tomb at, 31.
Cedar, 118, 119, 144, 147, 149.
Ceilings, plastered (*see* 'Plastering').
open timber, 147, 149, 150, 156.
Cement, Moxon's rules for making, 68.
Portland, 114–15.
Roman, 108.
Chaldea, brickwork in, 41–3.
Chalybes, 172.
Charlemagne, 266.
Chartres Cathedral, plumbing at, 250.
Chesterfield Church, lead spire of, 253–4.
Chestnut, 131, 153.
Chiddingfold, glassworks at, 269.
Chichester Cathedral, 91, 179, 183.
Chimneys, brick, 58–62.
stone, 96–8.
China, brickwork in, 42, 43.
origin of glazing in, 261.
Chipping Campden, 97.
Choisy *quoted*, 1, 15, 17, 41 *n.*, 42, 43 *n.*, 44, 45 *n.*, 47 *n.*, 73 *n.*, 76 *n.*, 77 *n.*, 79, 80 *n.*, 84 *n.*, 85 *n.*, 95 *n.*, 101, 102, 108 *n.*, 111, 112 *n.*, 118, 119 *n.*, 120, 122, 124 *n.*, 125 *n.*, 134, 136 *n.*, 206 *n.*, 207 *n.*, 208 *n.*, 209 *n.*, 211 *n.*, 212 *n.*
Christchurch Priory, 91.
Clermont-Ferrand, N. D. du Port, 88.
Cockerell, *quoted*, 79, 205.
Colchester, brickwork at, 56.
Coleshill, staircase at, 162.
sash-windows at, 279.
Collegia, Roman, 15, 17.
Colleyweston slates, 216.
'Comacine Masters', the, 21.
Concrete, CHAPTER IV (105–15).
in Egypt, 105.
in Mexico and Peru, 105.
Modern, 113–15.
Roman, 80, 81, 84, 106–11.
Constantinople, glassworkers at, 265–6, 268.
St. Sophia, 18, 48, 122, 268.
Corinth, masonry at, 77.
plastering at, 226.
Corneto, tomb at, 120, 226.
Cornwall, stone houses in, 95.
Corvée system, the, 11–12, 15, 17.
Cotswolds, stone houses in the, 95, 97–99, 215–16.
Coulton, G. G., *quoted*, 25.
Craftsmen, Assyrian, 13.
Egyptian, 9–13.
Greek, 14.
Medieval, 20–31.
Renaissance, 31–6.
Roman, 15–16.
Saracenic, 18.
Cramps in masonry, 77, 79, 89, 173.
Crete, brickwork in, 43.
joinery in, 147–8.
masonry in, 76.
plastering in, 225.
roofing materials in, 204.
timber from, 119, 149.
Crowhurst Place, ceiling at, 156.
Crusaders' influence on ironwork, 179, 181–3.
Crystal Palace, the, 200.
Ctesiphon, Great Hall at, 43.
Cummings, *quoted*, 86.
'Cyclopean' masonry, 76.
Cypress, 78, 119.
Cyprus, export of timber from, 122.

Damascening, 173, 182–3.
Damascus, glazing at, 266.
  Great Mosque, 122.
  Khan Asad Pasha, 164.
Damietta, brickwork at, 51.
  joinery at, 152.
Dance, George, 113.
Dawber, E. G., *quoted*, 62 *n.*, 99 *n.*, 131.
Day, L. F., *quoted*, 263 *n.*, 265 *n.*, 268 *n.*, 270 *n.*, 273, 274.
'Death-watch' beetle, 129, 253.
'Delta' brickwork, 51.
  carpentry, 123.
  joinery, 152.
Denderah, stone 'window' from, 260.
Devonshire, stone houses in, 95.
Diorite, use of, 72, 73 *n.*
Dog-bars, 190, 192.
Dolerite, use of, 73 *n.*
Donatello, 31, 230.
Door-furniture, 148, 159, 173, 182, 187.
Doors (*see* 'Joinery').
Dorset, stone slates in, 215.
Dosserets, 84.
Dowels in masonry, 75–6, 78, 79, 82, 89.
Duddington Church, 91.
Durham Cathedral, 178, 180.
'Dutch' glass, 272.

East Anglia, brickwork in, 51, 55–6, 58–9.
  carpentry in, 125, 133.
  flintwork in, 94.
  glazing in, 273.
  parging in, 133, 223, 234–6.
  tiling in, 217.
Eastbury Manor House, 58.
Easton stone slates, 216.
Ebony, 147.
Egypt, brickwork in ancient, 37–41.
  bronze work in, 116, 171.
  carpentry in, 116–18.
  concrete in, 105.
  craftsmen in, 9–13.
  ironwork in, 171.
  joinery in, 144–6.
  masonry in, 72–6.
  plastering in, 223–4.
  roof coverings in, 202–4.
Elm, 119, 131, 149, 152.
Eltham Palace, roof, 128.
Ely Cathedral, 112, 126, 127, 185.
Emery, use of, 74, 205.
'Enamel paint' on glass, 276.
Engelbach, *quoted*, 73 *n.*
'English' bond, 39, 51, 56, 70.
Essex, parging in, 234.
Etruscan bronze work, 172.
  carpentry, 118, 120.
  masonry, 80.
  plastering, 226.
  roofing materials, 204.
  terra-cotta, 204.
  vaults, 80.
Ezra, church of St. George, 84.

Fano, basilica at, 120.
Fenland churches, 90.
Fifehead Neville, Roman slates from, 208.
Fir, 119, 141.
Fire-backs, Sussex iron, 188.
'Flemish' bond, 56, 70, 109.
Flemish brickwork, 55–6, 57.
  glass, 272, 274.
  smiths, 187.
  steel, 198–9.
  tiles, 221.
Fletcher, H. M., *quoted*, 136 *n.*
Flintwork in East Anglia, 94.
Florence Cathedral (*Duomo*), 31, 55, 134, 169, 200.
  Pazzi Chapel, 134–5.
  Pitti Palace, 101.
  Strozzi Palace, 101–3.
Floyer, *quoted*, 57 *n.*
Folkestone, Roman Villa at, 245.
Fontana, Carlo, 10 *n.*, 120.
Forest of Dean, iron and steel from the, 175–6, 185, 188, 196, 198.
Foundations, concrete, 90.
  Egyptian, 39.
  Medieval, 90–1, 92.
  Moxon, *quoted on*, 69.
Fra Giocondo, 112.

France, early glassworkers in, 263–4.
medieval craftsmen and architects in, 29–31.
plumbing in, 250–2.
Renaissance architects in, 32.
slating in, 209, 216–19.
timber-framed houses in, 124, 216–19.
France, Anatole, *quoted*, 3 *n.*

Gardner, J. Starkie, *quoted*, 171 *n.*, 172 *n.*, 173 *n.*, 178 *n.*, 179 *n.*, 180 *n.*, 184 *n.*, 186 *n.*, 191 *n.*, 192 *n.*
Garner and Stratton, *quoted*, 132 *n.*
Gaul, ironworks in, 174.
Gedde, Walter, *quoted*, 277–9.
Genoa, polychrome masonry at, 94.
German brickwork, 52.
locksmiths, 187.
steel, 198.
Germigny-des-Près, plasterwork at, 229.
Gibbon, *quoted*, 16.
Gibbons, Grinling, 161, 236.
Girders, early iron, 200.
Roman, 173–4.
Gizah, pyramids of, 12, 74–5, 85.
Glass, crown, 270.
Dutch, 272.
Flemish, 272, 274.
grisaille, 270.
medallion, 270.
Normandy, 270, 272, 276.
plate, 282.
Venetian, 266, 272.
Glazing, CHAPTER XI (260–83).
Byzantine, 266, 268.
Gothic, 268–276.
Renaissance, 276–82.
Roman, 262–3.
Romanesque, 263–8.
Saracenic, 266–7.
Gloucester Cathedral, 271.
Gloucestershire, glassworkers in, 269.
steel, 198.
Godalming Church, lead spire of, 253.
Godstone, roof of cottage at, 130.
Godwin, G., *quoted*, 112 *n.*, 113–14.
Graining of joinery, 146, 149.
Granite, quarrying and use of, in Egypt, 72–6.
Great Chalfield Manor, half-timber at, 132.
Great Tangley Manor, half-timber at, 133.
Greece, craftsmanship in, 14.
Greek brickwork, 43–4.
bronze work, 172.
carpentry, 118–19.
joinery, 147–8.
masonry, 76–80.
plastering, 225–6.
tiling, 204–6.
Green, W. Curtis, *quoted*, 62 *n.*, 130 *n.*, 131.
Greenstead Church, 123.
Greenwich Hospital, plumbing at, 258.
Grilles, Gothic, 178–180, 189.
Roman, 174.
Romanesque, 178.
Saracenic, 182.
Grisaille glass, 270.
Groombridge Place, 71.
Guildhall Museum, London, 108, 207, 245.
Guilds, medieval, 25–6, 89.
Guizot, *quoted*, 21.
Gutters, lead, 210–12.

Hadrian, emperor, 15.
Haddon Hall, leadwork at, 246.
Half-timber work in France, 124, 130.
in Kent, 131–3.
in the Midlands, 130, 133.
in Surrey, 130–3.
in Sussex, 131–3.
Hamburg, brickwork in, 54.
Hammer-beam roofs, 128–9.
Hampton Court, brickwork, 57, 71.
carpentry at, 129.
ceilings, 231–2.

ironwork, 162, 190–1.
panelling, 157.
Hampshire, glassworkers in, 269.
Harmondsworth, roof of barn at, 130.
'Harrs', 159.
Hawara, brick pyramid at, 40.
Hawes, *quoted*, 44 *n.*, 77 *n.*, 149 *n.*, 225 *n.*
Heckington Church, roof of, 126.
Henry III, 27, 152, 247.
Herodotus, *quoted*, 241.
Hertfordshire, weather-boarded houses in, 133.
Highgate, Cromwell House, 161.
Hildesheim, door from, 180.
Hinges, 148, 152, 174–5, 177–80, 187, 199.
Hittorff, *quoted*, 80.
Holland, brickwork in, 52, 62, 67.
pantiles in, 220–1.
sash-windows in, 280.
Homer, *quoted*, 118.
Horsham stone slates, 216.
Houghton Hall, joinery at, 159.

Ibn Tulun, 18–19.
Ictinus, 14.
'Inblower', the, 141.
India, brickwork in, 42.
export of timber from, 122, 147.
Inlay, 146, 147, 150.
Innocent, C. F., *quoted*, 57 *n.*, 130, 160, 164, 214 *n.*, 217, 236 *n.*, 247 *n.*, 280 *n.*
Ironwork, CHAPTER VII (168–201).
Assyrian, 172.
Byzantine, 176.
Celtic, 176.
Chinese, 172.
Danish, 177.
Egyptian, 171.
Gothic, 178, 180–1, 181–5.
Indian, 172.
Renaissance, 186–200.
Roman, 173–6.
Romanesque, 177–80.
Saracenic, 181–3.

Jackson, Sir T. G., *quoted*, 18, 21, 22, 23, 33, 48, 86, 90–1, 92, 94, 128, 135, 208 *n.*, 232 *n.*, 266, 271.
Jarrow, Abbot of, 264.
Jerusalem, Church of the Holy Sepulchre, 245.
'Dome of the Rock', 121–2, 179, 208.
glazing at, 266.
Joggled lintels and voussoirs, 83, 85, 86.
steps, 86.
Joiners' tools, 147–8, 164–7.
Joinery, CHAPTER VI (143–67).
in the Bible, 147.
in Crete, 147–8.
Egyptian, 144–6
Gothic, 152–5.
Greek, 147–8.
in Mesopotamia, 146–7.
Renaissance, 154–9.
Roman, 148–9.
Romanesque, 152.
Saracenic, 149–52, 164.
Jones, Inigo, 33–4, 56, 99, 155, 156, 161, 236.
Justinian, emperor, 17, 18.

Kab, walls at el-, 41.
Karnak (*see* 'Thebes').
Kensington Gardens, the Orangery, 71.
Kent, brickwork in, 55, 58–62, 66–7.
carpentry in, 126.
glassworks in, 276.
steel, 198.
Kettering Church, leadwork at, 247.
Kirby Muxloe, brickwork at, 57.
Knole, lead pipe-heads at, 255.
Knossos, Palace at, 148.
plastering at, 225.
Knowles, J. A., *quoted*, 274.

Lacunae, 149.
Lane, E., *quoted*, 152, 164.
Langley, Batty, 36.
quoted, 64–6, 140–1.

Larch, 119.
Latches, iron, 189, 190.
  wooden, 162–4.
Laths for plastering, 132, 224, 227, 233.
  for tiling, 221–2.
Laud, archbishop, 276.
Lawrence of Chiddingfold (glazier), 269.
Layard, Sir A. H., *quoted*, 43 *n.*, 147 *n.*, 225 *n.*
Layer Marney Towers, 58.
Lead, Assyrian use of, 241.
  Byzantine use of, 85.
  casting, 248.
  dowels, 82.
  fonts, 245–6.
  Greek use of, 241.
  mines, 245.
  pipes, 241–5, 247, 254–6.
  'quarries' in windows, 279.
Lebanon, cedar from, 147.
Leonardo da Vinci, 32.
Lescot, Pierre, 136.
Lethaby, W. R., *quoted*, 18, 26, 110, 174 *n.*, 208 *n.*, 229, 241, 242, 245 *n.*, 247, 263.
Lewis, thatching in island of, 213.
'Lewis', Greek use of, 79.
Lime (Wood) for carving, 159.
Limes, Moxon *quoted* on, 67–8.
Limoges, glassworkers of, 266.
Lincoln Cathedral, 178, 252.
Lindisfarne, lead roof at, 246.
'Linenfold' panelling, 155.
Lingfield, Guest House, 130.
Locks, iron, 148, 159, 174, 187, 194.
  wooden, 162–4.
Lombard architecture, 20–1, 50, 53.
London (*see also* 'Westminster Abbey' and various museums).
  Ashburnham House, staircase, 162.
  Banqueting Hall, Whitehall, 99.
  City Churches, 104, 136, 190.
  City Companies, 26.
  Clifford's Inn, panelling from, 156.
  General Post Office, foundations, 113.
  glassworkers in, 276 *n.*
  Great Fire of, 35, 62, 63, 104, 133, 139, 190.
  Great George Street, panelling from, 156.
  Great Queen Street, old houses in, 280.
  Hatton Garden, panelling from, 156.
  Newgate Prison, foundations, 113.
  Old St. Paul's, lead spire, 254. 254.
  Roman Wall of, 108–10.
  St. Paul's Cathedral, 55, 99, 101, 136, 191–2, 200, 258.
  St. Stephen's Chapel, Westminster, 269.
  The Tower, 247.
  Waterloo Bridge, foundations of, 113.
  Westminster Hall, roof, 128.
Long Stanton Church, roof, 126.
Lorraine, glassworkers of, 276.
Lorsch, polychrome masonry at, 88.
Lubeck, brickwork in, 54.
Luxor (*see* 'Thebes').
Lycian carpentry, 118.
Lympenhoe Church, roof, 127.

Mace-rests, 190.
Mahogany, 159.
Mainz, Abbot of, 264.
Man, thatching in the Isle of, 213.
'Mansard' roof, 129, 135–6.
Mansart, François, 136.
  J. H., 136.
Maple, 149.
Marble wall-linings, 102–3, 106.
  roofing-tiles, 204–6.
Marquetry, Roman, 149.
Mashrabiyyah, 150–2, 183.
Masonry, CHAPTER III (72–104).
  Assyrian, 76.
  Byzantine, 84–5, 111–12.

in the Cotswolds, 95, 97–9.
in Crete, 76.
Egyptian, 72–6, 77.
Etruscan, 80.
Gothic, 86, 88–95, 112.
Greek, 76–80.
Persian, 76.
polychrome, 86, 87–8, 94, 98.
Renaissance, 99–104.
Roman, 80–4, 106–110.
Romanesque, 86–8.
Saracenic, 85–7, 88, 93, 98.
Syrian, 82, 83.
in Yorkshire, 95–6, 97–8.
Mayfield : Middle House, 133.
'Medallion' glass, 270.
Memphis, 263.
Mesopotamia (*see* 'Assyria').
Michelangelo, 32.
Middlesex, weather-boarded houses in, 133.
Middleton, J. H., *quoted*, 173, 242–4, 263 *n.*
Milan, S. Ambrogio, 52, 86.
Millar, W., *quoted*, 224.
Milled lead, introduction of, 258.
'Minoan' masonry, 76.
Mnesicles, 14.
Monreale, glazing at, 268.
Monte Cassino, bronze doors at, 176.
Montmartre, sash-windows at, 280.
Morris, William, 36, 282.
Mortar, Assyrian, 42.
Byzantine, 111–12.
Egyptian, 40, 74–5.
Medieval, 87, 90, 91, 112.
Moxon's recipes for, 67–8, 70.
Roman, 46, 106–8, 111–12.
Saracenic, 51.
Mosul metalwork, 182.
Moxon, Joseph, 35.
quoted, 66–71, 137–40, 143 *n.*, 158–9, 164–7, 196–200, 220–22, 237–9, 280.
Muqattam limestone, 72, 85.
Murano, glassworkers of, 270–1.
Muratori, *quoted*, 264.
'Mycenae, Lion Gate', 77.
Mycenae, masonry at, 76–7, 80.
plastering at, 225.
roofing at, 204.
Treasury of Athens, 172.

Naples, bronzes in museum at, 173, 244.
Narbonne, plaster window at, 230.
Nash, William, 237.
Naxos, 205.
Nebuchadnezzar, 172.
New Walsingham Church, roof, 125.
Nîmes, Baths of Diana, 82.
(*see also* 'Pont du Gard').
Nineveh, joinery at, 147.
use of iron at, 172.
Nonesuch Palace, leadwork at, 256.
Norfolk churches, 90.
Normandy, glassworkers in, 263, 270, 272, 276.
Northampton, St. Peter's Church, 88.
Northamptonshire ironworks, 185.
polychrome masonry in, 98.
North Walsham Church, roof, 126.
Norway Pine, 152.

Oak, 119, 122, 130, 131, 141, 152, 156.
Obelisks, Egyptian, 73 *n.*, 74, 75.
Oliver, B., *quoted*, 58 *n.*, 236 *n.*
Olympia, brickwork at, 44,
carpentry at, 119.
masonry at, 77.
tiling at, 204.
Opus incertum, 106.
reticulatum, 106.
Orange, Theatre at, 83.
Ould, E. A., *quoted*, 62 *n.*
'Overthrows', 190.
Oxford : Bodleian Library, ironwork at, 189.
glassworkers at, 276 *n.*
New College Chapel, windows, 281.

Oxford : contd. :
St. John's College, leadwork, 255.
Wadham College, 33.

Padua, roof-truss at, 134.
Paestum, masonry at, 77.
plastering at, 226.
Pain, William, 36.
quoted, 141.
Palermo, glazing at, 268.
Palladio, 134, 195.
Panelling, 147, 149, 150, 152, 154–9.
Pantiles, 217.
Parging in East Anglia, 133, 223, 234–6.
Parian marble, 206.
Paris : the Louvre, 33.
Notre-Dame, 180.
Place des Vosges, 212.
Pont Notre-Dame, 112.
Pasley, General, *quoted*, 114.
Pelasgic masonry, 76.
Pepys, Samuel, 63.
quoted, 133, 256.
Peperino stone, 80–1.
Périgueux, roofing at, 209.
Perrault, Claude, 33.
Persia, brickwork in, 42–3.
masonry in, 76.
Peruzzi, 101.
Peterborough Cathedral, 91, 112, 125, 153, 264.
Petrie, Sir W. Flinders, *quoted*, 11, 12, 41 *n.*, 73, 74, 116 *n.*, 117, 118, 145–6, 161, 224 *n.*, 241 *n.*, 261.
Petworth, lead pipe-head at, 256.
Philae, temples at, 39.
Philibert de l'Orme, 32–3, 135.
his roof-truss, 33, 134, 135.
Phoenicians, the, 119, 171, 245.
Pine, 119, 122, 149, 152, 153, 157.
Pisa, door from, 180.
Pipes, lead, 241–5, 247, 254–6.
Plans, medieval, 28.
Plasterers' tools, 224, 237–9.
Plastering, CHAPTER IX (223–39).
Assyrian, 224–5.
in Crete, 225.
in East Anglia, 223.
Egyptian, 223–4.
Etruscan, 226.
Gothic, 230.
Greek, 225–6.
Renaissance, 230–9.
Roman, 82, 225–9.
Romanesque, 229.
Saracenic, 230.
Plaster-of-Paris, 75, 223.
Pliny, *quoted*, 67.
Plumbers' Company, the, 247.
Plumbers' tools, 249.
Plumbing, CHAPTER X (240–59).
Medieval, 245–54.
Roman, 241–5.
Plutarch, *quoted*, 13.
Poitiers, roofing at, 209.
Poitou, glassworks in, 263.
Pollen, J. H., *quoted*, 149 *n.*, 153 *n.*
Polychrome masonry, 86, 87–8, 94, 98.
Pompeii, bronze work at, 173.
carpentry at, 83.
glazing at, 262, 263.
masonry at, 83.
Pont-du-Gard, masonry at the, 82, 84.
Pontus, use of iron in, 172.
Portland cement, 114–15.
stone, 104, 258.
'Pot-metal' in glazing, 270, 276.
Powell, H. J., *quoted*, 270 *n.*
Poynter, Sir E., 10.
Pozzolana, 108.
Pozzuoli, roof of shed at, 120.
Prior, E. S., *quoted*, 21.
Prisse d'Avennes, *quoted*, 41.
Prussia, steep roofs in, 210.
Purbeck marble, 88, 94.
Le Puy, ironwork at, 178.
polychrome masonry at, 88.
Pylons, Egyptian, 76.
Pyramids at Gizah, 12, 74–5, 85.
at Hawara, 40.

Quarries in glazing, 272–3.
lead, in windows, 277.
Quarrying, methods of, 72–3.

Rameses III, 11.
Ravenhead, glassworks at, 282.
Ravenna, Baptistery, 208.
  brickwork at, 48, 50.
  glassworkers at, 266.
  S. Vitale, 208.
  Tomb of Galla Placidia, 50.
  Tomb of Theodoric, 85.
Raynham, sash-windows at, 279.
Reader, F. W., *quoted*, 108–9.
Rejas, 185.
Reynolds, Sir Joshua, windows by, 281.
Rhamnus, temple at, 205.
Rhenish spires, 209.
Richborough, 22.
Rivoira, G. T., *quoted*, 50 *n.*
Rochester, iron railings at, 189.
Rogers, J. Thorold, *quoted*, 24.
Roman brickwork, 44–7, 106–11.
  bronze work, 173–4.
  carpentry, 119–21.
Roman concrete, 80, 81, 106–11.
  craftsmen, 15–16.
  glazing, 262–3.
  ironwork, 173–6, 200.
  joinery, 148–9.
  masonry, 80–4.
  mortar, 46, 81, 106–8.
  plastering and stucco, 82, 225–9.
  plumbing, 241–5.
  slating, 208.
  tiling, 206–7.
Romanesque brickwork, 52.
  bronze work, 176, 180.
  carpentry, 123–4.
  glazing, 263–8.
  ironwork, 177–80.
  joinery, 152.
  masonry, 86–8.
  plastering, 229.
  plumbing, 245–6.
  tiling, 208–9.
Rome: Basilica of Trajan, 120.
  Baths of Caracalla, 173.
  Cancelleria Palace, 101, 211.
  Cloaca Maxima, 80.
  Colosseum, 81.
  Farnese Palace, 211.
  'Hut of Romulus', 208.
  Lateran, 173.
  Pantheon, 173, 174, 206, 262.
  S. Francesca Romana, 52.
  SS. Giovanni e Paolo, 52.
  S. Maria Maggiore, 134.
  St. Peter's, 120.
  Tabularium, 80.
  Temple of Jupiter Stator, 83.
  Theatre of Marcellus, 81.
Roofs, timber (*see* 'Carpentry').
  drainage of, 210–12.
Roof coverings (*see also* 'Slating' and 'Tiling'), CHAPTER VIII (202–22).
  in Assyria, 204.
  in Crete, 204.
  Egyptian, 202–4.
  Greek, 204–6.
  Medieval, 208–17.
  Renaissance, 214–22.
  Roman, 206–8, 214.
  Saracenic, 122–3.
Rosetta, brickwork at, 51.
  joinery at, 152.
Rosewood, 147.
'Roundel' glazing, 183, 268, 274.
Ruskin, *quoted*, 36, 168–70, 200, 271.
Rye, brickwork at, 57.

St. Alban's Cathedral, 52, 112, 183.
St. Benedict, 21.
St. David's Cathedral, polychrome masonry at, 94.
St. Eloi, 246.
St. Paul-des-Champs, church of, 246.
St. Remy, Tomb of the Julii at, 206.
Saintes, roofing at, 209.
Salinas, Prof., *quoted*, 268.
Salisbury Cathedral, 90, 92, 94, 169, 200, 214.
Salzman, L. F., *quoted*, 23, 24, 26, 27, 28, 29.
Samarra, mosque at, 50.
Sanderson, G., *quoted*, 96 *n.*
Sandown, Yaverland Manor, 99 *n.*

Saracenic brickwork, 50–2.
bronze work, 182.
carpentry, 122–3.
craftsmen, 18–20, 182.
glazing, 266–7.
joinery, 149–52, 164.
masonry, 85–7, 88, 93, 98.
metalwork, 181–3.
plasterwork and stucco, 230.
roof-covering, 122–3.
Sash-windows, 279–81.
Sauval, *quoted*, 112 *n.*
Scaffolding, medieval, 27.
Roman, 82, 108.
Scott, Sir Walter, 91.
'Seasoning', of stone, 82.
Sempringham, door at, 152.
Sennacherib, 13.
Serbian brickwork, 48.
Sherwood Forest, ironworks in, 185.
Shingles, 209, 214.
Shutters, 260, 268–9.
Sicily, polychrome masonry in, 95.
Siena, palaces at, 101.
Silchester, glazing at, 263.
Silsilah stone, 72.
Simpson, F. M., *quoted*, 73 *n.*, 80 *n.*, 108 *n.*, 205 *n.*, 206 *n.*, 208 *n.*, 224 *n.*, 226 *n.*, 229 *n.*
Sizergh Hall, panelling from, 155.
Slates, stone, 95–6, 99, 209, 215–16.
Slating, French, 209, 216–19.
nomenclature of, 217.
ornamental, 216–19.
Welsh, 216–17.
Westmoreland, 216.
Smirke, Sir Robert, 113.
Smiths' tools, 196–7.
work (*see* 'Ironwork').
Soane Museum, London, 33.
Soane, Sir John, 113.
Sompting Church, spire of, 209.
South Kensington Museum (*see* 'Victoria and Albert Museum').
Southwold Church, flintwork at, 94.
Spain, brickwork in, 52.
ironwork in, 185.
Spalato, palace at, 83.
Spanish iron and steel, 188–9.
Spires, Rhenish, 209.
Staircases, 160–2.
'Stalactites', Saracenic, 86.
Stamford, St. Mary's Church, 91.
stone from, 90.
Steel, 172, 198–9.
Stillingfleet Church, ironwork at, 177.
Stogumber Church, knocker at, 184.
Stokesay Castle, windows at, 269.
Stone (Bucks.), roof of barn at, 130.
Stone slates, 95–6, 99, 209, 215–16.
Street, *quoted*, 53.
Stucco (*see* 'Plastering').
Suffolk, parging in, 234.
Surrey, brickwork in, 58–62.
carpentry in, 130–3.
glassworkers in, 269.
Sussex, brickwork in, 58–62.
carpentry in, 126, 131–3.
glassworkers in, 269.
ironworks in, 180, 185–6, 188, 195–6, 198, 214.
stone houses in, 95.
stone slates in, 215–16.
thatching in, 212–14.
Swedish iron and steel, 198.
Sword-rests, 190.
Sycamore, 122.
Syracuse, use of terra-cotta at, 119.
Syrian masonry, 82, 83.

Tadcaster, masons' wages at, 24.
Tattershall Castle, brickwork at, 56.
Teak, 147.
Terra-cotta, 52, 119, 204.
Tel el-Amarna, glassworks at, 261.
plaster floor at, 224.
Thatching, 212–14.
Thaxted, plastered house at, 236.

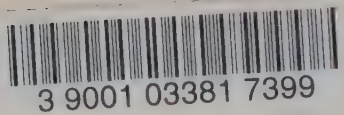
Thebaïd (*see* 'Thebes').
Thebes, carpentry at, 117.
'concrete' at, 105.
Karnak, temple of, 117.
masonry at, 72, 75.
Ramesseum, 41.
'window' from, 260.
Thorpe, John, 33.
Tibet, origin of brickwork in, 42.
Tijou, Jean, 162, 184, 190–2.
Tilers' tools, 222.
Tiles, paving, 67.
Tiling, Byzantine, 208.
in East Anglia, 217.
Greek, 204–6.
Renaissance, 217–220.
Roman, 206–7.
Romanesque, 208–9.
in Surrey and Sussex, 217.
Tiryns, brickwork of palace at, 43.
Tivoli, quarries at, 81.
Tools, bricklayers', 68.
carpenters', 116, 137–8, 171.
joiners', 147–8, 164–7.
plasterers', 224, 237–9.
plumbers', 249.
smiths', 196–7.
tilers', 222.
Toscanella, brickwork at, 52.
Toulouse, brickwork at, 54.
Transomes, brick, 58.
Transport, medieval, 27, 88–9.
Travertine stone, 80–1.
Trilithon at Baalbek, 84.
Troja Cathedral, bronze doors at, 176.
Troup, F. W., *quoted*, 248.
Tufa stone, 80–1, 90.
Turkey, export of timber from, 122.
Turner, L., *quoted*, 236 *n.*
Prof., *quoted*, 174–5.
Tuscany, polychrome masonry in, 94.
Twelvetrees, W. N., *quoted*, 105.

Vasari, *quoted*, 3 *n.*
Veneering, Roman, 149.
Venice, brickwork in, 48, 54.
Doge's Palace, 91.
Frari, 54.
glassworkers of, 266.
St. Mark's, 48, 176, 184.
steel, 198–9.
Verona, brickwork in, 54.
door from, 180.
Verre doublé, 273.
Verulamium, Roman brickwork from, 52.
Vézelay, polychrome masonry from, 88.
Victoria and Albert Museum, London, 149–51, 156, 157, 178, 179, 180, 183, 184.
Vignola, 35.
Villard de Honnecourt, 29–30, 124.
Viollet-le-Duc, *quoted*, 86, 124, 226 *n.*, 229 *n.*, 240–1, 248, 250–1, 252 *n.*, 266–7.
Vitruvius, *quoted*, 14, 16, 32, 44–6, 67, 82, 84 *n.*, 100, 106, 108, 119–20, 148, 174, 176, 195, 208 *n.*, 226–9, 242, 262.
Vosges, glass imported from, 272.

Wages of building craftsmen, 24, 137, 142, 191–2, 254, 273.
Walnut, 147, 159.
'Wattle and daub', 132.
Way, A., *quoted*, 177.
Weald, early iron industry in the, 180, 185–6, 188, 195–6, 198, 214.
Weather-boarded houses in Middlesex and Herts., 133.
Wearmouth, glazing at, 264.
Weaver, L., *quoted*, 247 *n.*, 255, 256.
Webb, John, 279.
Welsh slates, 216–17.
Westminster Abbey, 26, 112.
Chapel of the Pyx, 177.
Chapter-house windows, 268.
Grille of Eleanor of Castile, 181.
Henry VII's Chapel, 92.
Westmoreland slates, 216.
Whitby Abbey, 95.
Wight, stone houses in Isle of, 99 *n.*

Wilars d'Honecourt (*see* 'Villard de Honnecourt').
Wilderspool, glassworks at, 263.
William III, 57, 62, 190.
of Sens, 22.
Wilkinson, Sir G., *quoted*, 241.
Willis, *quoted*, 92,
Winchester Cathedral, 87, 91, 178.
glassworkers of, 276 *n*.
leadwork at, 255.
Palace at, 280.
St. Cross, 91, 128.
Wind bracing, 129.
Windows (*see* 'Glazing').
Windsor Castle, 27, 152.
St. George's Chapel, 180.
Wipley Farm, roof of barn at, 130.
Wolsey's work at Hampton Court, 57, 129, 231–2.
Wood, M. Paige, *quoted*, 214.
Worksop Priory, ironwork from, 180.
Wren, Sir Christopher, 34–5, 57, 71, 99, 102, 136–7, 153, 190, 236, 258.
Wyclif, *quoted*, 25.

Yaverland Manor, 99 *n*.
York, glasspainters of, 274, 276 *n*.
Minster, 23, 153, 246, 264.
Yorkshire, lead mines in, 245.
stone houses in, 95–6, 97–8, 215–16.
steel, 198.
'Yorkshire lights', 281.



Printed in England at the Oxford University Press

TH15
B7

Briggs
A short history of the building crafts